NASA Procedural Requirements

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COMPLIANCE IS MANDATORY

Subject: Facility Project Implementation Guide

Responsible Office: Facilities Engineering and Real Property Division

APPENDIX G: Sustainability

G.1 NASA's Facilities Program

G.1.1 Background. The NASA vision and missions suggest it must have a facilities infrastructure that is effective, efficient, safe, secure, and environmentally friendly, and a staff of facility professionals who are inspired, prepared, and capable of performing to the highest possible standards of their profession. Successful accomplishment of NASA missions requires all of its employees and contractors to constantly work at the cutting edge of their profession.

G.1.1.1 The cutting edge of today's facilities engineering profession is heavily focused upon improving the ultimate performance of capital plant projects. Areas receiving particular attention include the following:

a. Improving worker productivity resulting from improved building environmental ambiance and architectural aesthetics in a safe, secure, and more accessible workplace,

b. Minimizing a facility's impact upon the environment as a result of its construction, operation and ultimate decommissioning,

c. Improving facility performance in terms of energy efficiency, ease of maintenance, and improved facility system reliability, availability, operability, and durability,

d. Ensuring that projects ultimately perform to their design goals and objectives, and

e. Increasing emphasis upon facility life-cycle cost rather than first cost.

G.1.1.2 In 2002, facilities in the United States consumed 40 percent of the Nation's energy, 25-percent of harvested forests, and 17 percent of potable water produced. They generated 50-percent of chlorofluorocarbon emissions, 40 percent of landfill content, and 33 percent of carbon dioxide emissions. In 2002, NASA's infrastructure included over 5,000 facilities with about 44 million square feet on 400,000 acres of land. Annually, that infrastructure consumes nearly 10,000 billion British thermal units (BTU) of energy, and releases 270,000 tons of carbon emissions. Constrained budgets for operations and maintenance exceed $200 million annually.

G.1.1.3 This appendix introduces NASA facility professionals, and all others involved in the facility acquisition process, to the concept of sustainability, which encompasses industry practices of sustainable design, maintainable design, and building commissioning, and the important facility aspects of safety and security. The appendix provides a roadmap to enable facility professionals to plan, design, construct, activate, and maintain facility projects that: operate as intended; are maintainable at least cost and in a time sensitive manner; consume minimal energy and resources; and provide a safe, comfortable, secure and productive environment for NASA's research, test, production, institutional and administrative programs.

G.1.2 Section Content

G.1.2.1 Sustainability Concepts. Section 2 describes the concepts associated with sustainability, including subsections on the following:

a. Sustainability definitions,

b. Sustainability requirements and mandates,

c. The business case for implementing sustainability in NASA facilities,

d. Challenges to successfully implementing sustainability,

e. Existing NASA best practices, and

f. The sustainability team, process, and tools.

G.1.2.2 Sustainability and Project Planning. Section 3 includes the following subsections that describe how to apply sustainability concepts during the project planning phase of a facility acquisition:

a. An overview of the planning phase,

b. General sustainability issues to consider during the planning phase, and

c. Sustainability action items during the planning phases.

G.1.2.3 Sustainability and Project Design. Section 4 describes applicability of sustainability concepts to the project design phase, including subsections on the following:

a. An overview of the design phase,

b. General sustainability issues to consider during the design phase, and

c. Sustainability action items during the design phase.

G.1.2.4 Sustainability and Project Construction. The following subsections included in Section 5 describe applicability of sustainability concepts during the project construction phase:

a. An overview of the construction phase,

b. General sustainability issues to consider during the construction phase, and

c. Sustainability action items during the construction phase.

G.1.2.5 Sustainability and Project Activation. Section 6 describes applicability of sustainability concepts during the project activation phase, including subsections on the following:

a. An overview of the activation phase,

b. General sustainability issues to consider during the activation phase, and

c. Sustainability action items during the activation phase.

G.1.2.6 Sustainability during Operations and Maintenance. Section 7 describes the applicability of sustainability concepts after a facility has been accepted, and has moved into the operations and maintenance phase. Section 7 includes subsections on the following:

a. An overview of the operations and maintenance phase,

b. General sustainability issues to consider during the operations and maintenance phase, and

c. Sustainability action items during the operations and maintenance phase.

G.1.2.7 Sustainability During Facility Decommissioning. Section 8 describes the applicability of sustainability concepts at the end of a facilities life cycle. This period is referred to as the decommissioning phase. Section 8 includes sections on the following:

a. An overview of the decommissioning phase,

b. General sustainability issues to consider during the decommissioning phase, and

c. Sustainability action items during the decommissioning phase.

G.2 Sustainability Concepts

G.2.1 Definitions. Sustainability is not a new idea. Historically, Master Builders worked from a life-cycle perspective while operating in harmony with the landscape, the local climate, and the buildings of their neighbors. They made use of natural, locally available materials that were non-toxic to humans. They have long applied sustainable principles to their building designs and demonstrated their efficacy. The following definition for sustainability allows

NASA facility managers to address all three emerging practices (sustainable design, maintainable design and building commissioning, and appropriate safety and security issues) in one concept. The definition promotes integrating these concepts on all NASA facility projects.

G.2.1.1 Sustainability. An overarching concept incorporating appropriate sustainable design practices, maintainable design elements, building commissioning processes, and safety and security features into facility planning, design, construction, activation, operation and maintenance, and decommissioning to enhance and balance facility life-cycle cost, environmental impact, and occupant health, safety, security, and productivity. Done properly, sustainability will optimize the facility acquisition process to ensure the "best fit" of the built environment to the natural environment. It requires a practical and balanced approach to responsible stewardship of our natural, human, and financial resources.

G.2.1.2 Sustainable Design. A practice that involves planning, designing, constructing, activating, and operating buildings to reduce the negative impact on the environment, minimize energy consumption, and promote the productivity, health, and comfort of building occupants. The fundamental principles of sustainable design are the following:

a. Optimizing site potential,

b. Protecting and conserving water,

c. Minimizing energy use,

d. Using environmentally preferable products,

e. Enhancing Indoor Environmental Quality (IEQ), and

f. Optimizing operational and maintenance practices.

G.2.1.3 Maintainable Design. A practice that emphasizes the integration of operations and maintenance experience and principles into project planning, design and construction processes to achieve ease, accuracy, safety, and economy of maintenance tasks throughout the life of a facility. Maintainable design results in a facility that is durable, reliable, accessible, and operable. The following are fundamental principles of maintainable design:

a. Promoting participation and incorporating input by the O&M staff throughout the acquisition process,

b. Optimizing operation and maintenance practices and philosophy (using a combination of reactive, preventive, predictive and proactive maintenance strategies),

c. Emphasizing safety, accessibility, and ergonomics,

d. Minimizing the complexity and difficulty of maintenance tasks,

e. Using standard, interchangeable, and/or modular components, and

f. Measuring, trending and analyzing O&M performance, monitoring progress, and developing lessons learned throughout the facility life.

G.2.1.4 Building Commissioning. A quality process emphasizing procedures to ensure that systems are designed, installed, functionally tested, and capable of being operated and maintained to perform in conformity with the owner's project requirements. The process begins during project planning and extends through design, construction, activation, and operations and maintenance. Building commissioning concepts can be applied throughout the life of the facility. The fundamental principles of building commissioning are the following:

a. Identifying and documenting the functional requirements (user defined), facility requirements (as developed by the project team), and the basis and intent of the design,

b. Establishing processes to verify that project requirements are achieved; using a commissioning plan; using a commissioning authority; and including commissioning requirements in construction contracts,

c. Using functional performance testing and predictive technologies to ensure proper facility operation and to identify and eliminate latent defects prior to accepting new facilities or equipment by incorporating all the elements of NASA's RCBEA program, and

d. Measuring and documenting performance results throughout the acquisition process to ensure the project requirements are met.

G.2.1.5 Facility Safety and Security. Ensure project decisions include appropriate features to safeguard the health and welfare of facility visitors, occupants and equipment against internal hazards or external dangers (due to facility siting or terrorist activities). Safety and security issues must be considered during all phases of the facility acquisition process, and for the entire facility life-cycle.

G.2.2 Federal Mandates. This subsection addresses the primary laws, regulations and policies that require Federal

Agency action regarding sustainability.

G.2.2.1 The primary Federal mandate for sustainability is Executive Order (EO) 13123, Greening the Government Through Efficient Energy Management, dated June 3, 1999, is the primary order driving Federal agencies to develop sustainable design capability. Section 403(d) of EO 13123 requires Federal agencies to apply sustainable design principles to the "...siting, design, and construction of new facilities." The Department of Defense (DOD), the General Services Administration (GSA), the Department of Energy (DOE) and the Environmental Protection Agency (EPA) were tasked with developing the sustainable design principles. EO 13123 further requires agencies to "...optimize life-cycle costs, pollution, and other environmental and energy costs associated with the construction, life-cycle operation, and decommissioning..." of facilities. The order requires agencies to reduce energy consumption compared to 1985 and 1990 usage levels. Agencies were encouraged to meet the Energy Star building criteria for energy performance and indoor environmental quality by 2002.

G.2.2.2 Many other mandates require some aspects of sustainability on Federal facilities project, including:

a. The National Environmental Policy Act (NEPA) of 1969, which indirectly requires Federal facility managers to consider sustainability principals for construction projects.

b. Executive Order 12852 (EO 12852, 1993) established The President's Council on Sustainable Development (PCSD), a presidential advisory committee which adopted the following definition for sustainable from the World Commission on Environment and Development, Our Common Future: "...using resources today to meet the needs of the present without compromising the ability of future generations to meet their own needs."

c. Executive Order 12977 (EO 12977, 1995) created the Interagency Security Committee (ISC), headed by the Administrator of the General Services Administration, tasked with evaluating security standards for Federal facilities.

d. Executive Order 13101, Greening the Government Through Waste Prevention, Recycling, and Federal Acquisitions, dated September 14, 1998, requires Federal agencies to consider: using recovered materials; recycling; waste prevention and reduction; pollution prevention; and life-cycle costing in its daily practices. The order directed the EPA to develop a Comprehensive Procurement Guideline to make it easier for Federal agencies to identify and use environmentally friendly products. EO 13101 required Federal agencies to establish short- and long term goals for recycling or solid waste prevention.

e. Executive Order 13148, (EO 13148), Greening the Government Through Leadership in Environmental Management requires agencies to promote the sustainable management of Federal lands through cost-effective, environmentally sound landscaping practices, and other programs to reduce adverse impacts to the natural environment.

f. In response to the Energy Policy Act of 1992, the Department of Energy's Federal Energy Management Program (FEMP), in cooperation with The General Services Administration, developed the Building Commissioning Guide.

G.2.2.3 In 1994, the National Science and Technology Council of the Construction Building Subcommittee developed and published seven overarching National Construction Goals. These goals, to have been achieved by 2003, relate directly to sustainability concepts. The goals include the following:

a. Reduce project delivery time by 50-percent,

b. Reduce O&M and energy costs by 50-percent,

c. Increase occupant productivity and comfort by 50-percent,

d. Reduce occupant related illnesses by 50-percent,

e. Reduce waste and pollution by 50-percent,

f. Increase the durability and flexibility of facilities by 50-percent, and

g. Reduce construction illnesses and injuries by 50-percent.

G.2.3 NASA Mandates. NASA has several implementing policies and guidelines to ensure compliance with the Federal mandates. Two important NASA Procedural Requirements (NPRs) include NPR 8570.1, Energy Efficiency and Water Conservation Technologies and Practices and NPR 8820.3, Pollution Prevention . Specific sustainability requirements outlined in these two documents include the following:

a. Reduce overall energy use per gross square foot in nonmission variable buildings/facilities by 30-percent by FY 2005, and 35 percent by FY 2010, relative to FY 1985 levels.

b. Improve the energy efficiency of energy-intensive buildings/facilities (e.g. laboratories) 20 percent by FY 2005 and 25-percent by FY 2010, relative to FY 1990 levels.

c. Expand the use of renewable energy for facilities and operational activities by implementing renewable energy projects and by purchasing electricity from clean, efficient, and renewable energy sources so that the equivalent of

2-1/2 percent of facility electricity comes from new renewable sources by FY 2005 (1990 baseline).

d. Reduce greenhouse gas emissions attributed to facility energy use by 30-percent by FY 2010, compared to such emission levels in FY 1990.

e. Reduce the use of petroleum in facility operations by switching to a less greenhouse gas-intensive, nonpetroleum-based energy source where practical and cost effective and by otherwise improving the efficiency with which petroleum is used. EO 13149 sets a separate goal for motor vehicles - 20 percent reduction by FY 2005 from 1999 baseline.

f. Reduce water consumption and associated energy use by implementing appropriate Best Management Practices (BMP) identified by the DOE.

g. Reduce source energy even if site energy increases.

h. Comply with or exceed 10 CFR 434 Federal Energy Performance Standards for new construction.

i. Meet or exceed American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE)/ Illuminating Engineering Society of North America (IESNA) Standard 90.1-1999

j. Use ASHRAE Standard 55-1992, Thermal Environmental Conditions for Human Occupancy (1992) as the basis for thermal comfort. This standard sets forth temperature controls within facilities used for various applications.

k. Meet or exceed ASHRAE Standard 62-1999, Ventilation for Acceptable Indoor Air Quality, which establishes the minimum acceptable ventilation requirements.

l. This appendix will help project managers develop project specific goals that will contribute to meeting or exceeding the Agencywide goals listed above.

G.2.4. The Business Case for Implementing Sustainability in NASA Facilities

G.2.4.1 Facility owner and occupant benefits from implementing sustainability for a typical project include:

a. Reduced energy and water consumption,

b. Reduced waste streams and air pollution,

c. Reduced requirements for supporting infrastructure,

d. Reduced new equipment failure due to latent defects,

e. Extended equipment life and enhanced reliability,

f. Improved facility system availability, flexibility, and performance,

g. Reduced operations, maintenance, and decommissioning costs,

h. Reduced absenteeism and improved employee morale and productivity, and

i. Community recognition.

G.2.4.2 Implementing sustainability makes good business sense for NASA. It improves the balance between cost, schedule, and performance that is the ultimate objective of sound engineering practice.

G.2.4.3 When considered in total, the overall costs for planning and designing a facility are a relatively minor portion (typically about 10-percent) of the project's first costs. When compared to the much larger total life-cycle cost of the facility, including the costs for operations, they are an even smaller percentage (less than 1 percent). The implication is that almost any activity during project planning and design that identifies and incorporates features to reduce the project's operations, maintenance, labor, and production expenses will be cost effective over the facility life cycle. Many industry examples support this theory; including Lockheed's sustainability designed Engineering Building in Sunnyvale, California realized a 50-percent reduction in energy consumption and a 15-percent increase in worker productivity.

G.2.4.4 Industry experience indicates that many sustainability concepts with the potential for significant life-cycle savings can be incorporated at no increase in project first costs. Typically first cost increases for projects incorporating significant sustainability features range between 3-5 percent. Regardless of the extent to which sustainability is applied, the additional investments are highly likely to produce life-cycle paybacks. Properly implementing sustainability concepts may also extend a facility's useful life, and reduce the final facility shutdown and decommissioning costs.

G.2.4.5 The savings from implementing sustainability concepts contain many subjective elements, including improved employee morale and effects of environmental improvements (higher productivity, less sick leave), making them difficult to quantify within a life-cycle analysis. Industry advocates estimate that the direct and indirect savings are several times greater than any additional first costs. The goal of sustainability is to implement the discipline during project planning, design, construction, and activation, that will exploit every opportunity to reduce project life-cycle costs while enhancing the projects environmental impact and overall maintainability, safety, and productivity.

G.2.5 Challenges to Successful Implementation.

NASA Policy Document 8820.3 establishes sustainability as an Agency objective for all new projects. This policy mandates Centers to implement sustainability concepts on future projects.

G.2.5.1 A significant challenge to successfully and routinely implementing sustainability concepts on NASA facility projects is overcoming the tendency for decision makers to focus on first costs instead of life-cycle costs. Although many sustainability concepts can be implemented without increasing first project costs, some do require an additional initial investment. The existing Federal facilities project acquisition process devotes a significant amount of attention on project first costs. Funding for project design and construction is managed separately from funding for operations and maintenance. This funding structure creates incentives to lower first costs, freeing up funding for additional design and construction projects, or increases in specific project scopes.

G.2.5.2 Some people believe building commissioning would not be necessary if the owner hires qualified design professionals and skilled contractors who are responsible for delivering fully functional facilities. Several factors conspire to frustrate this reasonable expectation: increasingly complex and interdependent building technology, downward pressure on professional fees, highly competitive low-bid construction acquisition procedures, detachment of designer and builders from the realities of operating and maintaining facilities, inadequately defined owner project requirements, and lack of experience in demonstrating the functional integrity of components and systems under a full range of operating conditions. Therefore, for many projects commissioning is an appropriate process to ensure success.

G.2.5.3 Successfully and fully implementing sustainability concepts on projects requires a new mindset. Existing paradigms among project stakeholders must change. Early participation from all project stakeholders will be required. Use of emerging technologies must also be accepted, and guide specifications must be adjusted to incorporate changing materials and practices.

G.2.5.4 Many aspects of sustainable design practices, maintainable design elements, and building commissioning processes are applicable to renovation projects. Much less energy and resources are needed to produce construction materials and deliver them to the site when the building's basic shell is being reused. Older buildings, in particular, make excellent candidates for low-energy design that utilizes their mass, higher ceilings, and narrower building form. Project teams must deal with some fixed constraints in renovation projects, including the building's site, orientation, massing, and structural systems.

G.2.6 Existing NASA Best Practices. NASA Centers have successfully implemented practices of RCBEA, Preproject Planning, Constructability, Value Management, Partnering/Teambuilding. Sustainability is integrated into and fully supports the fundamental concepts of these best practices.

G.2.6.1 RCBEA focuses on using predictive technologies to identify latent defects in building systems and equipment prior to acceptance. Properly applied, RCBEA reduces incidence of infant mortality, and ensures NASA obtains the full life and usefulness of installed equipment.

G.2.6.2 Preproject Planning (P3) is a powerful and methodical process to ensure project criteria, goals, and objectives are identified before design start. The P3 process also establishes the project team. Sustainability introduces some additional elements into the P3 process to achieve sustainability criteria, goals and objectives (such as building commissioning requirements, and increased emphasis on specific sustainable design, maintainable design and safety and security alternatives).

G.2.6.3 The process for evaluating Constructability has many similarities with maintainable design. Both processes ensure that design decisions that will impact subsequent facility life-cycle phases (i.e., cause undue construction, operations or maintenance problems) are not overlooked during project planning and design. Sustainability, and in particular the maintainable design element, provides additional emphasis on the operations and maintenance aspects following construction completion.

G.2.6.4 Value Management involves seeking opportunities to improve project cost, schedule, or performance features. Sustainability will enhance the value management approach, by providing significantly increased emphasis on life-cycle considerations, and ensuring that all project alternatives and competing interests are addressed during the development of the owner's project requirements.

G.2.6.5 Partnering and Teambuilding focuses on effectively involving a wide range of project stakeholders to ensure project success. Sustainability also advocates wide participation to ensure that all stakeholders have an opportunity to contribute to project requirements and objectives. The team approach forces informed decisions and compromises that are in the best long-term interest of the overall organization.

G.2.6.6 NASA's progressive operations and maintenance programs include Reliability Centered Maintenance (RCM). The RCM approach and using predictive technologies for building and equipment acceptance follow principles found in the maintainable design and building commissioning practices. NASA's energy and environmental programs are also very proactive and have achieved significant success.

G.2.6.7 NASA's Reliability Centered Building and Equipment Acceptance program emphasizes the use of predictive technologies and inspections to identify latent defects during the construction and activation phases of a project. This approach is reinforced by the sustainability concepts included in this appendix, including the building commissioning and maintainable design elements.

G.2.6.8 The material in this guideline acknowledges these ongoing programs, and where appropriate, acknowledges the interface and integration with them.

G.2.7 The Sustainability Team.

G.2.7.1 Successfully implementing sustainability requires teamwork. The team, organized and working together from the project inception, must integrate sustainable design concepts in the planning and design process, seeking creative solutions to design challenges that yield multiple benefits. Rather than optimizing individual systems, the project team must understand that the most effective results are obtained by designing various building systems and components as interdependent parts of the entire structure.

G.2.7.2 FPIG Section 3.4 discusses Preproject Planning and the team concept. A successful project team for sustainability complements the Preproject Planning process, and should include the following members:

a. Facility Project Manager, to provide overall leadership that ensures that competing interests are properly balanced and ultimately achieved.

b. Sustainability Champion, who understands sustainability principles and concepts, and how to successfully integrate them into the project.

c. Center Planning Staff, to provide guidance regarding broad goals and objectives for facility development.

d. Architects, Engineers and Designers, including in-house and contractor members to develop the plans and pecifications.

e. Contracting Representative, to advise on acquisition related issues.

f. Construction Manager, to advise on constructability related issues.

g. Operations and Maintenance Personnel, to address long-term operations and maintenance requirements for the facility and to share and capture maintenance lessons learned.

h. Safety and Security Representatives, to ensure appropriate measures are taken to safeguard people and property.

i. Environmental and Energy Managers, to help identify targets for energy and environmental consumption, and to ensure projects support meeting or exceeding mandates for their programs.

j. Customer, to identify final operating objectives. Ideally, the customer representative has long-term responsibility for O&M and program requirements. In the NASA environment, this is often not the case.

k. Commissioning Authority (CA), to ensure that operation of the final constructed facility meets the owner's project requirements. The CA is involved from planning through design, construction, and activation.

G.2.8 The NASA Sustainability Practice.

G.2.8.1 The extent to which sustainability should be pursued on a project depends upon the individual project's size, mission criticality, location, complexity, and available funding. This appendix suggests actions throughout the planning, design, construction and activation phases to ensure that the facility requirements are met. The NASA sustainability practice is intended to produce healthy debates and appropriate tradeoffs between competing requirements (i.e., should the facility have operable windows (sustainable design attribute), small fixed windows (a maintainability feature), or no windows (a security consideration)?).

G.2.8.2 The NASA sustainability practice parallels the building commissioning practice. Building commissioning is aimed at ensuring that the owners project requirements are achieved during the planning, design, construction and acceptance phases. Traditionally, building commissioning has focused upon testing, acceptance, and final operability of a constructed facility. The NASA sustainability practice includes other facility performance criteria, including criteria for sustainable design, maintainable design, safety and security. The practice reinforces the NASA RCBEA practice of using predictive technologies to identify and eliminate latent defects from facilities or equipment installation projects.

G.2.8.3 NASA Centers must submit an annual report of their progress toward implementing the policies described in NPD 8820.2, Design and Construction of Facilities. These annual reports will require Centers to focus on their level of commitment to sustainability principles, and report specific metrics related to that program. The annual reporting requirements will evolve, but are initially established to include the following:

a. Projects

(1) Percentage of A-E contracts awarded requiring sustainability experience as an evaluation factor in contract award,

(2) Number of construction projects using an independent commissioning agent, and

(3) The number of design and/or construction projects with sustainability achievements or elements.

b. Training

(1) Number of Center personnel that attended the NASA Sustainability Best Practices II course,

(2) Number of Center personnel that attended the NASA Reliability Centered Building & Equipment Acceptance course, and

(3) Number attending and description of any other Sustainability related training courses received.

G.2.9 Sustainability Tools. Many tools exist to help project managers understand and implement sustainability. The primary tools project teams should use include the following:

a. The Leadership in Energy and Environmental Design (LEED) rating system,

b. The Whole Building Design Guide (WBDG),

c. The Building for Environmental and Economic Sustainability (BEES) guideline,

d. The EPA and DOE's Energy Star© Program,

e. DOE's Energy 10 Program,

f. DOE's DOE-2 Energy Program,

g. The Construction Industry Institutes Design for Maintainability Guidebook (IR142-2),

h. The General Services Administration and Department of Energy's Building Commissioning Guide,

i. Model Commissioning Plan and Guide Specifications,

j. NASA's Reliability Centered Building & Equipment Acceptance Guide,

k. NASA NPG 8831.2D, Facilities Maintenance Management,

j. DOD Technical Manuals for Security Engineering, (TM 5-853-1 through 5-853-4), and

k. GSA Public Building System P-100, November 2000

G.2.9.1 All NASA projects will be evaluated for sustainability achievements using the LEED™ - Green Building Rating Systemdeveloped by the U.S. Green Building Council (USGBC). LEED™ is a nationally recognized sustainable facility performance standard. Designed for rating new and existing commercial, institutional, and high-rise residential buildings, it is self-certifying. It is a feature-oriented system where credits are earned for many criteria, including: siting, water efficiency, energy and atmosphere, materials and resources, and indoor environmental quality. The LEED system includes varying levels of certification, including Certified, Silver, Gold, and Platinum levels. The USGBC is piloting a version of LEED for existing buildings, which will allow ratings for renovation projects of existing facilities.

G.2.9.2 The WBDGis a comprehensive internet-based gateway to a wide range of Federal and private sector buildings-related guidance, criteria, and technology. The WBDG was developed by several Federal agencies in response to a mandate within Executive Order 13123. The WBDG links information across disciplines and traditional professional boundaries, and encourages integrated thinking and a whole building performance perspective. The recommendations within the WBDG will help improve the performance and quality of facility projects. The WBDG includes a significant listing of energy analysis tools useful for determining energy impacts of various design alternatives. The WBDG is hosted and managed by the National Institute of Building Sciences (NIBS).

G.2.9.3 The Building Environmental and Economic Sustainability software tool is a building materials analysis program developed by the National Institute of Standards and Technology (NIST). BEES measures the environmental performance of building products by using the environmental life-cycle assessment approach specified in ISO 14000 standards. All stages in the life of a product are analyzed: raw material acquisition, manufacture, transportation, installation, use, and recycling and waste management. Economic performance is measured using the ASTM standard life-cycle cost method, which covers the costs of initial investment, replacement, operation, maintenance and repair, and decommissioning. Environmental and economic performance is combined into an overall performance measure using the ASTM standard for Multi-Attribute Decision Analysis.

G.2.9.4 Energy Star© was introduced by the EPA in 1992 as a voluntary labeling program designed to identify and promote energy-efficient products to reduce carbon dioxide emissions. EPA partnered with DOE in 1996 to promote the Energy Star© label, with each agency taking responsibility for particular product categories, including residential heating and cooling equipment, major appliances, office equipment, lighting, and consumer electronics. Commercial and K-12 school buildings that are among the top 25-percent Nationwide in terms of energy performance (earning a benchmarking score of 75 or greater on a scale of 0 to 100) and maintain an indoor environment that conforms to industry standards can qualify to receive the Energy Star© label for buildings. During 2001, NASA qualified two of its facilities with the Energy Star© label.

G.2.9.5 DOE's ENERGY-10© is a software program designed for smaller residential or commercial buildings that can be treated as one or two-zone increments. It performs whole-building energy analysis for 8760 hours/year, including dynamic thermal and daylighting calculations, and is specifically designed to facilitate the evaluation of energy-efficient building features in the very early states of the design process.

G.2.9.6 DOE's DOE-2© is an hourly, whole-building energy analysis software program calculating energy performance and life-cycle cost of operation. It can be used to analyze energy efficiency of given designs or the energy efficiency of new technologies. Other uses include utility demand-side management and rebate programs, and development and implementation of energy efficiency standards and compliance certification.

G.2.9.7 The CII Design for Maintainability Guidebook IR 142-2 is a manual providing recommended practices and a variety of checklists, guidelines, and illustrative examples intended as implementation tools for achieving a high level of project maintainability. The research team responsible for this manual included NASA personnel, while the team documented and analyzed specific NASA projects at the Johnson Space Center. This resource includes a self-assessment that will define the organizational "level of maintainability"; describes a model implementation process; and provides specifics on more than 22 recommended maintainability practices and 16 tools to help implement these recommended practices. The CII education module presents maintainability concepts and practices described in the Design for Maintainability Guidebook.

G.2.9.8 The Building Commissioning Association's Building Commissioning Attributes is a short document that defines Essential Attributes and Valuable Elements of commissioning (http://www.bcxa.org/attributes.htm). The Building Commissioning Association (BCA) recommends that owners incorporate these attributes in their commissioning programs. Members of the BCA must agree to perform commissioning in accordance with the Essential Attributes to ensure the integrity and effectiveness of the commissioning process.

G.2.9.9 The General Services Administration and Department of Energy's Building Commissioning Guide and the companion Model Commissioning Plan and Guide Specifications provide a detailed discussion of how to implement the commissioning process on Federal projects. The Model Commissioning Plan and Guide Specifications include specific forms and procedures that may be adapted to the commissioning needs of a specific project.

G.2.9.10 NPR 8831.2D, Facilities Maintenance Management describes the practices and procedures Center's should be employing to ensure their operations and maintenance programs are effective. This NPG provides an excellent reference regarding O&M requirements that should be considered during project planning and design phases.

G.2.9.11 The NASA Reliability Centered Building & Equipment Acceptance Guide provides suggested contract language, test procedures, and test limits for using predictive technologies to identify latent defects in installed equipment. The project team should rely upon this resource to ensure appropriate testing is performed for critical equipment.

G.2.9.12 The Department of Defense Technical Manuals for Security Engineering, TM 5-853-1 through TM 5-853-4, May 1994 provides guidelines for designing federal facility projects in response to potential terrorist threats. The four manuals include considerations during the project planning (TM-5-853-1), concept design (TM 5-853-2), and final design (TM 5-853-3) phases, and also include planning and design requirements for electronic security systems (TM 5-853-4).

G.2.9.13 The GSA Public Building System P-100, November 2000.

G.2.10 The NASA Acquisition Process. The FPIG describes requirements for completing projects through the planning, design, construction and activation phases. This appendix in addition addresses requirements during the operations and maintenance and decommissioning phases. Figure G.2 identifies each acquisition phase. The significant steps in successfully implementing sustainability concepts are listed for each phase.

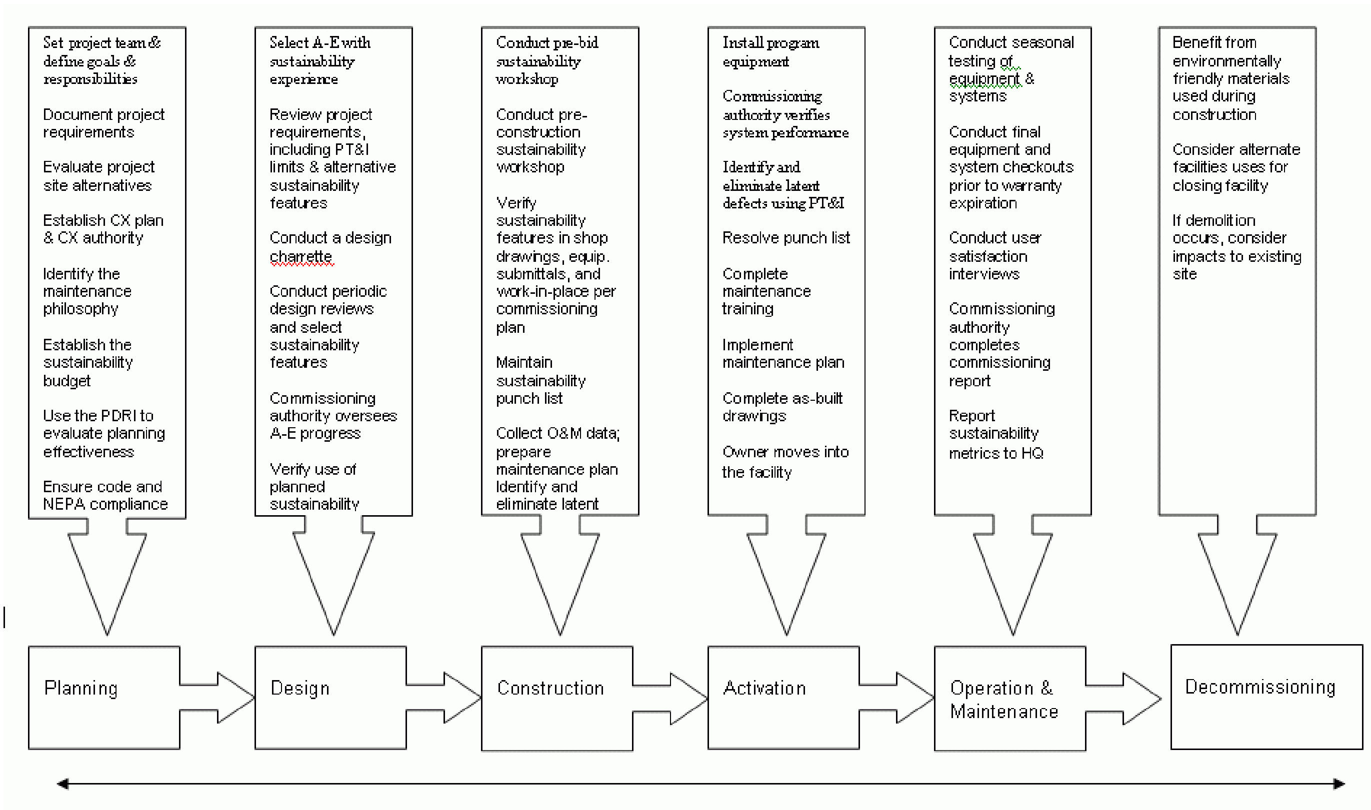

Figure G.2 - Phases of Facility Acquisition

G.3 Project Planning

G.3.1 Overview

G.3.1.1 Decisions made during the project planning phase set the project tone and direction, and have the greatest impact upon facility life-cycle costs. Establishing sustainability project goals, defining the process to achieve them, and developing a clear understanding of the expected results will enable project success. A clearly developed project framework guides the decision-making process throughout the project, incorporating issues related to site selection, facility and system designs, the construction process, activation, facility operations and maintenance, and decommissioning.

G.3.1.2 During this phase, the project team documents the project requirements. Section 3 of the FPIG fully describes this requirements development process. Final project requirements are included in the facility Requirements Document (see FPIG Section 3.7, Requirements Document), which includes: user functionality and special needs, the local context and community issues, codes and regulations to emphasize, site and climate issues, building context and function, and building technology considerations. Examples of sustainability requirements that should be addressed in the Requirements Document include:

a. Building commissioning requirements,

b. Indoor environmental quality goals (i.e., maximum allowable carbon dioxide concentration, minimum ventilation effectiveness, desired temperature and humidity levels),

c. Lighting quality and illumination intensity,

d. Power quality and availability,

e. Maintainability requirements, including accessibility, reliability and availability, and

f. Energy use goals.

G.3.1.3 For small projects and rehabilitation or renovation work, the Requirements Document may be quite simple. For example, in a project to upgrade the fire alarm system, the Requirements Document may state, "Provide a state-of-the-art fire alarm system that meets current code, improves the protection of personnel, operates for 72 hours independent of external power, and communicates with the existing central monitoring and notification system with no more than one error per month."

G.3.1.4 Where practical, specific project requirements should be measurable. When criteria are measurable quantities, results can be compared to determine whether the requirements have been met. Rather than asking for an "energy efficient" building, the criteria might be written to require that energy consumption during the first 5 years of operation be 10-percent lower than required by ASHRAE Standard 90.1.

G.3.2 Planning Phase General Sustainability Issues.

G.3.2.1 Balance Competing priorities. Considering the many elements of sustainability early during the planning phase, and assessing impacts of various design alternatives, will maximize the degree to which sustainability elements can be implemented without increasing project design or construction costs. Sustainable design, maintainable design, building commissioning, safety and security objectives will differ among projects. Many factors will influence the degree to which elements of each component of sustainability can be implemented. For each project, many issues will dictate final requirements, including: budget constraints, schedule considerations, facility size, hours of operation, utility rates, code requirements, siting constraints, local climate, existing maintenance organization and philosophy, and existing threat environment.

G.3.2.2 Hire Experience. NASA shall select A-Es and construction contractors with proven sustainability experience. This guideline and the training workshops that reinforce its concepts will enable NASA project engineers to understand sustainability, but ultimate success will depend upon having experienced designers and contractors as an integral part of the project team.

G.3.2.3 Acknowledge the facility maintenance philosophy. Acknowledge the Center's facility maintenance philosophy, and address reliability and availability requirements. The maintenance philosophy considers an appropriate mix of reactive, preventive, predictive and proactive maintenance tasks. It considers contractor capabilities and contract requirements from the Center Operations Support Services (COSS) contract. The user and Center facility engineers must determine reliability and availability issues. More detailed discussions on NASA operations and maintenance program are included in NPR 8831.2D.

G.3.2.4 Involve Center O&M staff. COSS contractors perform operations and maintenance functions at all NASA Centers. Any decisions regarding sustainability, especially those related to maintainable design, should be made with the COSS contractor in mind. Project decisions should consider the need to perform maintenance tasks efficiently and safely. Input from the maintenance staff and COSS contractors will enhance maintainability design decisions.

G.3.2.5 Consider the Center Master Plan. Specific project requirements should consider and reflect the planning criteria with the Center Master Plan.

G.3.2.6 Address Safety and Security Concerns. NASA emphasizes the safety and security for its employees, assets and visitors. Safety and security are included within the umbrella of facility sustainability. NASA Policy Directive 8700.1 (NASA Policy for Safety and Mission Success) and NASA Procedures and Guidelines 8715.3 (NASA Safety Manual) address safety requirements for NASA facilities programs. Within the Federal government, there is a wealth of reference material for considering special safety and security requirements associated with terrorist attacks. The best reference for planning and designing Federal facilities is the Department of Defense Technical Manual 5-853, Security Engineering. This four-part technical manual includes planning and design guidance and information on electronic security systems.

G.3.2.7 Start the Building Commissioning Process. It is important to start the building commissioning process during the project planning phase. Building commissioning verifies that the facility requirements are well documented and provides the process for ensuring they are achieved. The facility Requirements Document provides the foundation for the design, construction, activation, operation, and maintenance of the facility, and is the basis for the commissioning plan and schedule. The Requirements Document should define the scope of commissioning and suggest the CA. The CA may be an independent consultant, a member of the Architect-Engineer firm, or a NASA employee, depending upon the scope and complexity of the project requirements.

G.3.2.8 Select a Commissioning Authority. For Centers embarking on their first few commissioning experiences, hiring an independent CA may be beneficial. Attachment 2 provides guidelines for selecting a CA. For smaller projects, or after experience is developed, the CA functions may be performed using in house expertise. The CA workload varies depending upon the phase a project is in, and is most intense during the final stages of construction and the activation phase.

G.3.3 Action Items. Considering the following action items during the planning phase will help the project maximize sustainability objectives within existing constraints. Attachment 1 includes a list of reference documents that provide more detailed information regarding many of these action items.

G.3.3.1 Define Responsibilities and Procedures. Within the project team identified in section 2.6.1, assign responsibilities for managing the project and the sustainability program. Use formal or informal partnering within the team to ensure early buy-in, commitment, and understanding of project sustainability goals. The NASA Partnering Desk Reference Guide (available on the NASA Headquarters Code JX Web site) defines the partnering process. At an initial project meeting, the team should discuss procedures used to exchange information throughout the project life.

G.3.3.2 Conduct a project planning charrette. A charrette is an intensive, collaborative effort involving many project team members to quickly examine project alternatives. A planning charrette will allow project team members to develop project goals, and to discuss alternatives to achieve them. The charrette will ensure appropriate options are reviewed, allow debate regarding competing project priorities, and bring the team into alignment prior to moving forward in the acquisition process.

G.3.3.3 Identify Project Sustainability Goals. Identify and describe the project's sustainability goals as part of the facility Requirements Document. The facility user requirements will dictate how aggressively each sustainability concept can be pursued. In particular, the environmental needs of each space (e.g. the desirability of daylighting, specific temperature/humidity conditions, acoustical requirements) must be considered. Sustainability goals should consider the maintenance strategy for the project, as well as safety and security considerations. Where practical, the goals should include measurable results (i.e., degree of energy consumption), which can be measured once the facility is completed. At a minimum, the goals should address the following:

a. Environmental impacts,

b. Energy conservation,

c. Use of renewable energy sources,

d. Use of environmentally preferable materials,

e. Life-Cycle Costs,

f. Indoor environmental quality,

g. Employee safety and security,

h. Operations and maintenance considerations including availability, ease of maintenance, access and safety,

i. Commissioning, and

j. Decommissioning.

G.3.3.4 Identify Certification Goals. Specify the Leadership LEED sustainability certification level desired, and identify if the project will be submitted for the Environmental Protection Agency's Energy Star rating program.

G.3.3.5 Develop A-E and Construction Contractor evaluation criterion. Establish an evaluation criterion for selecting Architect-Engineers, construction contractors and commissioning agents based upon their experience and ability with sustainability concepts.

G.3.3.6 Establish the Sustainability Budget. Set the project budget based on the design alternatives with the lowest total life-cycle cost. Identify the budget requirements to achieve the sustainability goals. Some sustainability concepts may increase the first costs of the project. The project team should conduct a life-cycle cost analysis to demonstrate the merit for incurring these additional first costs.

G.3.3.7 Use Life-Cycle Cost Analysis. Project decisions shall be driven by life-cycle cost analysis, rather than impacts only on first project costs. The life-cycle cost resource page on the Whole Building Design Guide provides an excellent tool.

G.3.3.8 Consider lessons learned. A lessons learned database supports the recording, archiving and accessing of lessons learned and best practices from other, similar projects. Evaluate if lessons learned are available. If appropriate, benchmark with other agencies to identify lessons learned. Use the NASA Lessons Learned Information System (LLIS) database to share lessons learned throughout the Agency.

G.3.3.9 Establish the Commissioning Plan. The commissioning plan captures important decisions about commissioning and ensures that everyone understands their responsibilities. The commissioning plan should incorporate or reference the owner's project requirements (OPR), identify the Center's commissioning goals, identify the CA and commissioning team members and their roles, establish the scope of commissioning in terms of systems and equipment, outline the major commissioning steps during design, construction, activation and operation, and discusses lines of communication and authority.

G.3.3.10 Evaluate Siting Alternatives. Identify and evaluate possible siting alternatives, considering solar gain (consider atrium spaces, direct or indirect passive solar heating, earth-protected spaces, and natural and constructed shading), daylighting, building orientation, and window placement. These considerations must be balanced against concerns for safety and security. Siting considerations should also consider landscape plans that contribute to the facility's energy performance (shading options, windbreaks, and use of existing site or building features) and impacts upon the natural environment.

G.3.3.11 Consider Renewable Resources. Investigate the use of renewable power sources as part of the facility's overall power supply. Consider using solar (domestic) hot water on building types with high hot water usage, such as laboratories, and Building-Integrated Photovoltaics (BIP) to reduce reliance on nonrenewable power.

G.3.3.12 Conduct a preliminary energy analysis. Consider doing a preliminary energy analysis using Energy-10 and the latest version of DOE-2 or other applicable tool for larger and more complex projects. For smaller, simpler projects (those with two or fewer zones or less than 50,000 SF), consider using other less complex energy analysis tools.

G.3.3.13 Consider resource conservation and recycling issues. Develop resource conservation strategies to limit environmental damage and maximize opportunities for reuse. Assess the direct and indirect environmental impacts of building material selections.

G.3.3.14 Consider Sustainable Technologies/Techniques/Processes. The team should evaluate using the following:

a. Passive solar technologies,

b. Daylighting,

c. Sun controls and shading,

d. Energy efficient lighting and controls,

e. Energy efficient windows,

f. Natural ventilation,

g. High performance HVAC equipment and systems,

h. Advanced environmental management control systems,

i. Underfloor air distribution,

j. Fuel cells,

k. Distributed energy,

l. Building Integrated Photovoltaics (BIP),

m. Solar water heating,

n. Biomass and biofuels,

o. Gray water and rain catchment systems,

p. Porous paving surfaces,

q. Water conserving (ultra low flow) devices,

r. Wind energy systems,

s. Xeriscaping, and

t. Microturbines.

G.3.3.16 Consider maintainable design issues. Maintainable design issues to consider during the planning phase include the following:

a. Acknowledge the Center maintenance philosophy, and balance reactive, preventive, predictive and proactive maintenance strategies accordingly,

b. Identify critical systems for the facility, and associated availability and reliability requirements,

c. Evaluate equipment choices with consideration of life-cycle costs, spare parts, maintenance staffing, standardization and interchangability, modularization, operability, maintenance task complexity, and maintenance access,

d. Establish project maintainable design metrics for inclusion in the overall OPR (i.e., target maintenance costs/SF, mean time to repair, mean time between failures, reliability measures),

e. Consider required data to support a Computerized Maintenance Management System,

f. Identifying warranty issues,

g. Identify appropriate RCBEA specifications and test procedures,

h. Consider requirements for appropriate devices to support efficient predictive testing processes, and

i. Identify staffing or training issues related to facility operations and maintenance.

G.3.3.16 Consider building commissioning issues. Building commissioning issues to consider during the planning phase include the following:

a. Quantify performance criteria for critical systems, and acceptance criteria and testing including Predictive Testing & Inspection (PT&I) limits to identify latent defects,

b. Identify systems to be commissioned,

c. Select the CA and establish their contract,

d. Create a preliminary commissioning plan, and

e. Establish A-E design phase deliverables in support of the commissioning process.

G.3.3.18 Consider Safety and Security issues. Safety and security issues to consider include the following:

a. Conduct a preliminary threat and vulnerability assessment. NASA Headquarters and Center Directors should have appropriate guidance regarding threat conditions at each Center,

b. Evaluate blast mitigation measures (stand off distances, blast walls, and blast resistant materials) that may affect planning parameters,

c. Consider access control requirements for NASA employees and visitors, including traffic patterns, barriers, delivery access, locks, and interface with security forces,

d. Consider requirements for heating, ventilation and air conditioning systems, including need for zoned systems, and access to air intakes,

e. Identify security lighting and electronic security system requirements, and

f. Complete a hazards analysis to identify and evaluate safety and risk considerations.

G.4 Design

G.4.1 Overview

G.4.1.1 During the design phase, the team creates a design with project plans and specifications that form the basis for a construction contract award. Design phase decisions regarding materials, technologies, and systems for the project will significantly affect its degree of sustainability. Once the design proceeds toward completion, opportunities to impact the life-cycle costs for the facility diminish rapidly. This section provides guidance and action items to help maximize the sustainability, meet the project requirements established during the planning phase, and produce more efficient NASA facilities.

G.4.1.2 The FPIG design reviews occur at the 30-percent, 60-percent and 90-percent stages. During these reviews the project team should assess whether sustainability enhancements and considerations have been properly applied.

G.4.2 General Sustainability Issues during the Design Phase

G.4.2.1 During the design phase, many of the project planning assumptions and decisions will be evaluated in detail. Final decisions will be made which will irreversibly affect the life-cycle performance of the project.

G.4.2.2 General sustainability issues to address in the design phase include the following:

a. Select an A-E and Commissioning Authority with Experience. Ensure the architects-engineers and consultants used on the project have experience and demonstrated capability in sustainability and commissioning practices.

b. Conduct a design charrette. The design charette process allows debate and decisions regarding competing project priorities, and helps the team select the optimal alternatives. The charette brings the team into alignment prior to moving forward in the acquisition process.

c. Conduct formal and informal design review meetings. The project team should review the specific elements of sustainability at each design review to ensure the project will achieve satisfy stated requirements. Between formal 30-percent, 60-percent and 90-percent reviews, it is appropriate to have other informal meetings to address specific sustainability elements individually.

d. Document Design Decisions. The project team should have a process for recording information about project development decisions. It is very important to document decisions made throughout the acquisition process, especially where tradeoffs must be made between competing priorities.

e. Use CII Design for Maintainability Guidebook. Refer to the CII Guidebook for specific Maintainable Design technologies and ideas.

f. Continue the Building Commissioning Process.

(1) At the beginning of the design phase the CA guides the project team in updating and completing the project commissioning plan. The commissioning plan includes actions required to achieve the project requirements. As the project requirements are translated into design documents, the designers create a basis of design document to convey the assumptions made while completing the design. Commissioning specifications detail the construction contractor's responsibilities for commissioning work, including documentation, testing, and final acceptance.

(2) Projects using the commissioning process require additional design generated documents beyond the traditional plans and specifications. The design team will need to create one-line diagrams of all systems (similar to electrical one-line diagrams), control logic diagrams (piping & instrumentation diagrams for control systems, interface wiring diagrams of communication links between systems, basis of design documentation, and design calculations. The design team shall also ensure commissioning specifications are developed for: appropriate accommodations for testing and monitoring data collection; and the ability of selected equipment and systems to operate under all loads and conditions.

g. Identify and Eliminate Latent Defects. Select and specify appropriate predictive testing and inspection requirements with specific acceptance criteria and acceptance limits, to identify and eliminate latent defects from critical installed equipment. Refer to the NASA RCB&E Guideline for more detailed guidance.

G.4.3 Action Items. The sustainability team shall perform these action items during the Design Phase to ensure the project maximizes sustainability objectives.

G.4.3.1 Maximize Site Potential - Action items to consider include the following:

a. Recognize that some sites may not be suitable for new or additional development,

b. Minimize the building footprint and associated access and parking facilities,

c. Minimize developing open space by selecting already developed land,

d. Preserve flexibility for future development adjacent to the site,

e. Integrate the building into the natural setting, preserving natural attributes and minimizing tree and vegetation destruction,

f. Orient the facility to take advantage of sun angle and wind direction, leveraging passive measures to reduce energy consumption,

g. Minimize distance from adjacent buildings, and provide pedestrian-friendly settings to minimize dependence on motor vehicles,

h. Provide bicycle racks and shower facilities to encourage alternate commuting options,

i. Provide refueling/recharging facilities for alternative fuel/electric vehicles,

j. Provide properly located sidewalks lighted for security and traffic-calming measures (i.e., narrower roads with speed controls for pedestrian safety),

k. Reduce heat islands through landscaping (i.e., use existing trees to shade walkways and parking lots) and building design methods (i.e., light-colored roofing),

l. Mitigate noise levels, both from the surroundings and from building operations by using berms or tree filters, and

m. Site facilities to accommodate the watershed drainage, and to take advantage of the visual and thermal qualities of water in land use planning.

G.4.3.2 Protect and Conserve Water - Action items to consider include the following:

a. Provide rainwater catchment areas, and segregate gray water and potable water systems. Recover nonsewage and gray water for onsite use,

b. Provide onsite gray water distribution systems and waste-treatment,

c. Develop strategies for mitigating runoff (all construction activities disturbing 1 or more acres must apply for National Pollution Discharge Elimination System (NPDES) permit coverage for storm water as required by the Storm Water Phase II Final Rule (64 FR 68722),

d. Provide water and condensate recovery systems and water-conserving cooling towers,

e. Use indigenous plants and beneficial landscaping to minimize irrigation needs,

f. Use pervious surfaces for low-traffic volume roadways and parking areas and biofiltration swales and retention ponds to minimize infiltration and runoff, and

g. Use water efficiently through ultra-low-flow fixtures, water-conserving cooling towers, and other actions (i.e., sensor faucets).

G.4.3.3 Minimize Energy Consumption - The design team should evaluate the appropriateness of each of these energy saving alternatives using life-cycle cost analysis. Alternatives to consider include the following:

a. Building energy performance must meet or exceed 10 CFR 434 requirements.

b. Buildings must have meters for all energy sources and potable water supplies.

c. Use the natural attributes of a site for optimal lighting, ventilation, heating, and cooling. Consider options like solar shading for summer, stone masonry during winter to take advantage of seasonal changes in solar radiant heat gain. Use colors that reflect or absorb solar radiation. Place and sizing openings appropriate to the solar angles.

d. Integrate technologies, including solar energy, wind energy, fuel cells, biomass energy, and microturbines, to further reduce nonrenewable energy consumption.

e. Use trees and other vegetation to redirect prevailing winds, and to shade the structure.

f. Reduce the facility's surface-to-volume ratio while maintaining useable spaces to accommodate user activities.

g. Increase absorption wall mass to enhance thermal storage (e.g. Trombe walls, where desirable).

h. Apply controllable natural ventilation, or airtight insulation to match the climactic conditions.

i. Specify efficient e- and R-values for windows, doors and wall insulation, and window operability.

j. Incorporate structural measures including overhangs, light wells, photovoltaic cladding, ceiling height, and facility dimensions that will leverage increased energy efficiency of the integrated mechanical and electrical systems.

k. Optimize the sizing of heating, ventilation and air-conditioning equipment against reduced heating and cooling loads of lighting and the building envelope.

l. Optimize cross-ventilation or use ceiling fans where natural ventilation is feasible.

m. Select energy-efficient heating, ventilation, air conditioning, and humidity conditioning equipment, and high-efficiency variable speed motors and fans. Control and monitor these systems using an Energy Management Control System.

n. Consider humidity conditions appropriate for the intended use.

o. Design the HVAC system to exceed ASHRAE Standard 90.1-1999 for thermal comfort requirements.

p. Comply with indoor air quality standards (ASHRAE 62-1999) while minimizing energy required to condition fresh intake air and using heat exchangers between intake and exhaust ducts.

q. Use high efficiency, solar assisted hot water heaters for large hot water loads, and on-demand water heaters for low loads.

r. Minimize pipe lengths where central hot water storage and chilled water is required.

s. Consider cogeneration to produce heat and hot water from a single-power source (e.g., reuse the hot water or steam generated by fuel cells).

t. Specify Energy Star™ office equipment and appliances (e.g. computers, copiers, printers, fax machines, refrigerators, microwaves, washers and dryers) and select energy efficient installed equipment, such as elevators and water heaters.

u. Use shared natural daylighting, (e.g., skylights, clerestories, light shelves) to reduce the need for artificial lighting.

v. Use area-specific lighting levels that will allow reduced ambient lighting levels and energy-efficient, low-heat-producing, electronically ballasted lamps and fixture with automatic controls.

w. Consider thermal storage.

x. Consider relationship of the facility to campus-wide utility systems.

G.4.3.4 Use Environmentally Preferable Products - Action items to consider include the following:

a. Check with Center Environmental Program Managers for listing of environmentally preferable products, programs, or specifications that may already be developed.

b. Avoid using endangered, nonrenewable products.

c. Design building dimensions to allow for use of resource-efficient systems (e.g., matching building dimensions to standard-size furniture and interior fittings to eliminate waste created through custom fitting).

d. Use demountable and reusable interior building components to accommodate changing facility requirement.

e. Specify durable, low-maintenance materials or encouraging the use of recyclable assemblies and products that can be deconstructed at the end of their useful lives.

f. Specify locally available materials with manufacturing processes that optimize benefits to local economies.

g. Specify materials harvested on a sustained-yield basis, such as lumber from certified forests.

h. Eliminate the use of materials that pollute or are toxic during their manufacture, use, or reuse.

i. Identify materials covered by the Recovered Materials Advisory Notices issued by the Environmental Protection Agency under its comprehensive procurement guidelines.

j. Apply the BEES software developed by the National Institute for Standards and Technology to select materials with the desired combination of environmental benefits.

G.4.3.5 Enhance IEQ - Action items to consider include the following:

a. Use materials that minimize noise pollution and toxic emissions,

b. Maximize use of daylighting,

c. Provide for sufficient replenishment of fresh air,

d. Provide a well-designed interior environment that is visually and acoustically pleasing,

e. Ensure acoustic privacy and comfort through the use of sound-absorbing material and equipment isolation,

f. Consider noise levels appropriate for the intended use,

g. Provide thermal comfort with maximum personal control over temperature and humidity,

h. Control disturbing odors through contaminant isolation and proper ventilation,

i. Provide separate chemical storage areas with separate ventilation,

j. Install a permanent air-monitoring system to ensure compliance with indoor air quality objectives,

k. Locate air intake ducts away from fume-producing areas, such as loading docks and driveways,

l. Use separate ventilation for interior work areas that produce noxious fumes,

m. Reduce or eliminate materials (paint, carpet, particleboard, adhesives) that contain toxic or hazardous substances, such as lead, asbestos, and volatile organic compounds, that affect human health,

n. Replace ozone-depleting substances such as chlorinated fluorocarbons in refrigeration equipment and specify PCB-free transformers and other electrical equipment, and

o. Provide radon infiltration barriers if required.

G.4.3.6 Consider the Existing Center Maintenance Strategy - The Center strategy suggests the degree of application of modern maintenance practices, use of COSS contractors to operate and maintain systems, and availability of equipment and resources for performing maintenance practices. The project team should consider the maintenance strategy when evaluating these action items for the project. Action items to consider include the following:

a. Review the maintenance philosophy and objectives identified during the planning phase with the sustainability team; the philosophy should comply with existing NASA policies and guidelines (i.e., NPR 8831.2D, Facilities Maintenance Management).

b. Prioritize the systems and equipment according to their criticality to the facility operations.

c. Identify those systems or equipment that might require specialized maintenance practices, including special design consideration or application of predictive maintenance practices.

d. Identify equipment and devices required for predictive testing and condition monitoring, and ensure they are included in the computerized maintenance management system.

e. Include Center O&M staff, including (COSS) contract staff, in the design review process. The COSS contract requirements and capabilities should be considered in design decisions.

f. Consider the Computerized Maintenance Management System (CMMS), and requirements to provide appropriate equipment inventory, scheduled maintenance tasks, warranty, parts information, and condition monitoring results into the CMMS.

g. Establish maintainable design metrics to measure the degree of success. Metrics might include: maintenance costs per facility square foot; mean time to repair; reliability or availability percentages; mean time between failure. These metrics will enable the team to measure project success upon completion.

h. Provide O&M staff with results of any failure analyses performed on critical equipment during the design process.

G.4.3.7 Review Maintenance Safety, Accessibility and Ergonomics - Action items to consider include the following:

a. Consider ergonomics for O&M personnel, including: height and location of equipment; easy and clearly identified access points for maintained components; minimal equipment in high locations; proper illumination in maintenance spaces and display panels; convenient hoisting mechanisms where required; noise levels of equipment that won't impede staff performance or maintenance activities,

b. Consider temperature, humidity, and other environmental considerations relative to the location and operating environment of critical equipment,

c. Provide appropriate access to operate and maintain equipment and systems. Some of the more important access considerations include: size and location of doorways, elevator or lift requirements for higher floors, hinging or release mechanisms on access plates or doors, tool requirements for access doors, labeling of access panels or doors, and

d. Provide removable insulation for piping at maintenance access points, and provide reasonable access points for pipe chases and ducts.

G.4.3.8 Minimize Maintenance Task Complexity - Action items to consider include the following:

a. Consider operations and maintenance task complexity when selecting equipment,

b. Provide clearly written and readily accessible maintenance guidelines,

c. Consider requirements for spare parts and tools when selecting equipment, and

d. Consider the environmental conditions when locating equipment requiring significant maintenance activity (situations where O&M personnel will be subjected to temperatures above 90 degrees or below 40 degrees).

G.4.3.9 Use Standardization, Interchangeability and Modularization of parts and systems - Action items to consider include the following:

a. If Center standards exist, specify common equipment to avoid the need for multiple suppliers, spare parts, and training requirements;

b. Specify standard equipment racks and consoles for similar equipment;

c. Specify common modules for similar equipment;

d. Use common nomenclatures, preferably using a Centerwide standard;

e. Where cost effective, specify plug in modules or components that can be replaced without tools, and repaired in controlled environments;

f. Where possible, design systems to allow single component or module replacement without impact to other components or modules to avoid damage to associated equipment;

g. Specify common fasteners throughout specific systems; and

h. Minimize the number of piping systems, sizes of pipes, and variance in pipe materials.

G.4.3.10 Consider Safety and Security - Action items to consider include the following:

a. Review safety and security issues identified during the planning phase regarding hazards analysis, threat and risk assessment, blast mitigation requirements, access control, lighting, and security systems. This information forms the basis for beginning design development for safety and security.

b. Evaluate seismic zone requirements. If not in seismic zones 3 or 4, evaluate if additional structural hardening is appropriate to mitigate collapse.

c. Identify security lighting and electronic security system requirements.

d. Consider access control requirements, including traffic patterns, barriers, delivery access points, locks, and interface with security forces.

e. Refer to Department of Defense Security Engineering Technical Manuals 5-853-1 thru 5-853-4, and GSA's Public Building Services P-100, which provide more detailed guidance for evaluating appropriate security requirements in

Federal facilities. The Architect-Engineer team should review these requirements and propose appropriate security measures given the threat assessment, facility location, and facility criticality.

f. Consider accessibility requirements for people with disabilities.

G.4.3.11 Support Building Commissioning - Action items to consider include the following:

a. Provide control logic diagrams - Control logic diagrams, or detailed pseudo-code consisting of if-then statements, define the required control of systems with less ambiguity than text-based sequences of control. These should be complete at the end of schematic design.

b. Provide one-line system diagrams - One-line diagrams of all mechanical services, similar to plumbing riser diagrams, are necessary to clarify and troubleshoot system operation. These also should be complete at the end of schematic design.

c. Provide interface wiring diagrams - Interface wiring diagrams eliminate the ambiguity of system connections. The diagrams show communication or signal wiring interfaces between systems, indicating the panels, wiring configuration, and the nature of the signals. These also should be drafted at the end of design development and completed in the construction documents.

d. Document the Basis of Design. The design team documents the basis of design, which includes among other things: outdoor summer and winter design conditions, indoor summer and winter environmental comfort requirements, lighting parameters, power quality and reliability, utility capacities at the site, assumptions about types of use and occupancy schedules. The CA reviews the Basis of Design for compliance with the facilities Requirements Document.

e. Conduct a Commissioning Design Review. Review the project design at the 30-percent, 60-percent and 90-percent stages. The project team, led by the CA, ensures the design properly considers the OPR, and evaluates: system operation under all operating conditions and loads; that adequate access is provided for safe, cost-effective maintenance and operation; and that system interfaces are designed to function as intended. During early design stages, the reviews focus on appropriate system selection, and adequacy of space for mechanical and electrical equipment.

f. Adjust the Commissioning Plan. The CA adjusts the commissioning plan throughout the design phase based upon decisions and changes as the project matures. Changes are common on most projects, and may be the result of changing user requirements, technology improvements, budget concerns, schedule concerns, or other factors. The commissioning plan includes sections regarding the following important areas:

(1) Lines of communication and authority for commissioning team members,

(2) Listing of shop drawings and product submittals requiring CA review, and

(3) Functional testing requirements throughout the construction and activation phases.

g. Prepare Commissioning Specification - The commissioning specification should be developed during the design phase. In some instances, a set of draft functional performance test (FPT) and RCB&E predictive testing procedures and data forms is included in the bid documents in place of the FPT descriptions. This gives construction contractors an advance understanding of their commissioning testing requirements. The downside of this approach is the volume of paper added to the bid package, and the need to adjust the procedures to after approved shop drawings and product submittals are received. The commissioning specification identifies the commissioning work required by the construction contractor, and will include the following:

(1) Qualification requirements for someone to lead the contractor's commissioning efforts;

(2) Requirements for submittal and shop drawing reviews;

(3) Requirements to submit and manage the commissioning schedule, integrated with the construction schedule;

(4) Reporting and documentation requirements;

(5) Requirements for completing FPT, and RCB&E predictive testing to identify latent defects, during the construction and activation phases. Test specifications should describe for each test: the systems and equipment to be tested; the functions to be tested; the conditions for the testing; and the measurable acceptance criteria; and

(6) Closeout requirements tied to the general conditions of the construction contract.

G.5 Construction

G.5.1 Overview

G.5.1.1 The construction phase presents many opportunities to stray from a well-developed sustainable design. During construction, the building commissioning aspect of sustainability moves to the forefront, as plans and specifications give rise to a fully functioning and sustainable facility.

G.5.1.2 During construction, the sustainability team will exercise the construction phase elements of the commissioning plan, performing important shop drawings and material submittal reviews, functional performance and RCB&E tests, and quality assurance checks. This section provides a checklist of action items to follow during the construction process. The ultimate objective is to produce a facility that meets documented facility requirements.

G.5.2 General sustainability issues to consider during the Construction Phase

G.5.2.1 The roles and emphasis of sustainability team members change as the project moves into the construction phase. Operations and maintenance personnel increase their involvement to ensure equipment meets minimum maintainability requirements. Building commissioning takes on an increasingly more important role during the construction phase. The interface between the construction contractor, commissioning authority, and other team members becomes very important to the success of the project.

G.5.2.2 The volume and pace of activity during the construction process increases. Good communication regarding submittals, approvals, schedules and project progress is essential to allow the project to remain on schedule, within budget, and moving to achieve the project requirements.

G.5.3 Action Items. The project team should consider the action items in the following paragraphs during the construction phase to ensure the project maximizes sustainability objectives established in the facility requirements document and developed in the final project design.

G.5.3.1 Construction Contractor Selection - Many construction contracts are awarded to the lowest responsive, responsible bidder in a firm fixed priced, sealed bid approach. The team should consider an award based upon best value, considering price and other technical factors. One technical criterion for the best value evaluation process is the contractors experience and understanding of sustainability.

G.5.3.2 Conduct a preconstruction partnering session - The partnering session provides an opportunity to bring the newly selected construction contractor onto the project team, and to establish working relationships and project expectations. All team members will begin to understand the project objectives. Process issues should be discussed, including submittal and shop drawing reviews and approvals, conduct and timing of functional performance and RCB&E testing, access to the project site by O&M personnel, and other required building commissioning efforts.

G.5.3.3 Require an indoor environmental quality plan - To reduce negative impact on the building and building occupants, especially during renovation projects, require an Indoor Environmental Quality Plan. With regard to construction, the IEQ plan should include requirements for protecting the building materials, sequencing material installation, ventilation requirements, and keeping the site clean and hazard free. The Sheet Metal and Air Conditioning Contractors Association has an Indoor Air Quality (IAQ) guideline for buildings under construction, IAQ Guidelines for Occupied Buildings Under Construction.

G.5.3.4 Require site conservation practices - The construction contract should require the contractor to preserve the integrity of the site and existing habitat. Enforcement of these requirements (erosion control, tree cutting) is important to sustaining the existing site.

G.5.3.5 Minimize Construction Wastes - The construction contract should emphasize minimizing wastes generated during the construction process. The design and subsequent construction should emphasize source reduction, materials reuse, and waste recycling. Source reduction is most relevant to new construction and large renovation projects and involves reduced "waste factors" on materials ordering, tighter contract language assigning waste management responsibilities among trade contractors, and value-engineering of building design and components. During renovation and demolition, building components that still have functional value can be reemployed on the current project, stored for use on a future project, or sold on the salvage market. Recycling of materials can be accomplished whenever sufficient quantities can be collected and markets are readily available. Management and minimization of hazardous materials disposal is also very important.

G.5.3.6 Establish a Submittal Review and Approval Process - Requiring the contractor to provide materials that comply with project specifications, and support sustainability requirements are critical. The project team should have a clearly established review and approval process that involves the proper team players without unduly delaying the construction contractor. Materials should be evaluated to ensure they are meeting environmentally preferable product requirements, energy consumption requirements, maintainability requirements (standardization, complexity, maintainability), and functional requirements. Where appropriate, the Center may have a preferred supplier list or request proprietary items to support overall maintainability or environmental objectives.

G.5.3.7 Schedule Periodic Site Walk Throughs - Coordinate periodic site walk throughs to familiarize O&M personnel with the facility during construction, and before components become hidden by wall, ceiling or floor covering. Special attention should be paid to accessibility and maintainability issues during the walk throughs.

G.5.3.8 Building Commissioning during Construction - Commissioning activities during construction include scheduling and coordinating designated submittal reviews, functional performance and RCB&E testing, finalizing

FPT and RCB&E procedures and data forms for later use, observing construction for commissioning-related issues (such as location and sizing of control components), performing static tests, and beginning operator training. This sets the stage for energizing and functionally testing systems during project activation. Specific actions on a typical project might include the following:

a. Prebid Meeting - If appropriate, conduct a prebid meeting to ensure that bidders are aware of their commissioning responsibilities.

b. Update Commissioning Plan - Update commissioning plan to include information about the contractors and suppliers selected, including details of lines of communication for commissioning correspondence and notifications. Having the construction contractor copy the CA on certain types of correspondence can improve coordination without compromising the chain of command.

c. Update Commissioning Schedule - The contractor integrates commissioning activities into the master construction schedule. Commissioning activities and milestones should be tied to appropriate predecessor construction activities, should have estimated durations and completion dates, and be tied to dependent activities. As construction progresses, the contractor updates and refines the commissioning schedule items at each submittal of the construction schedule.

d. Commissioning Coordination Meetings - Conduct periodic commissioning coordination meetings to review the commissioning schedule, submittal status, upcoming functional performance testing, and results of recent tests. Attendees should include the construction contractor, CA, appropriate design team staff, project manager, Quality Assurance (QA) staff, and on occasion O&M, energy or environmental representatives. For convenience, these meetings often follow the construction progress meetings.

e. Commissioning Submittal Review - Primary responsibility for review of contractor shop drawings and product submittals remains with the designers of record. However, the CA should review submittals critical to the commissioning process concurrently. These include all control system equipment, shop drawings, and control logic or program code submittals, and submittals of central equipment such as boilers, chillers, generators, fans, pumps, meters, and switchgear. The commissioning review focuses on the ability of the submitted equipment and control logic to meet the project requirements.

f. Functional Performance and RCB&E Testing (FPT) Procedures and Data Forms - The CA or the contractor G.5.3.8. generate original FPT and RCB&E test procedures and data forms, or update the draft FPT procedures and forms (from the bid documents), to correspond with the approved equipment and control logic submitted by the contractor. If the CA updates the draft procedures, the contractor should review them to identify: any safety concerns; procedures that cannot be executed with the approved equipment or control logic; and for options to perform the FPTs more efficiently. The procedures and data forms contain the detailed instructions on how to execute the tests and what information to record. Procedures contain sufficient detail that any competent technician can perform the test without further instruction, with repeatable results. Data forms provide space to record observed performance. Attachment 3 provides an example FPT specification.

g. CA Observe Construction - The CA observes important aspects of construction adds focus on issues of accessibility, maintainability, and "commissionability." Commissionability means that equipment and systems can be tested to verify they perform as intended. For example; flow sensors and meters located too close to a fitting cannot provide accurate flow information; or lack of test ports may preclude measuring system performance; or there may not be safe access to air terminal units in a crowded ceiling.

h. Static Tests - The contractor performs and the CA observes static tests. Examples of static tests include pipe and duct leak tests, and cable insulation integrity tests. Because of their importance to subsequent commissioning activities, static tests should be administered under the same stringent procedures as FPT's. They should follow written procedures, have measurable acceptance criteria, and the written test data should become part of the commissioning record. Static tests are prerequisites to component and system FPT's.

i. Predictive Testing to Identify Latent Defects - The contractor performs and the CA observes RCB&E tests using predictive technologies aimed at identifying latent defects in installed equipment.

j. Operations and Maintenance Program - Throughout the construction phase the sustainability team should be tailoring the O&M program to support the installations maintenance philosophy. O&M manuals providing information on the operation and maintenance on the installed equipment are required. These manuals are typically supplied by the construction contractor and their equipment suppliers; however, the FPM may satisfy this requirement using other means. The O&M program within the project should support the Center's O&M program philosophy. Contractors must provide information electronically, and with enough detail to support interface with the Center's CMMS system. Manufacturer warranty information and manuals should be compiled for easy access and interface with the CMMS system.

k. Operations and Maintenance Training - O&M training must start during construction to ensure the O&M staff is ready to operate the facility upon final completion. Designers, contractors, and the CA participate in training to convey the knowledge each of them has gathered during the project. Review training materials and the qualifications of trainers to ensure effective delivery. Videotape formal training sessions for future use.

G.5.3.9 Safety and Security During Construction - The project team should ensure appropriate safety guidelines are followed during the construction process. The process of building commissioning should ensure required safety and security systems are installed and operate as designed.

G.6 Activation

G.6.1 Activation Overview.

G.6.1.1 During activation the contractor is still on site resolving punch list items and completing required commissioning testing. Facility occupants are moving furniture, equipment, and in some cases personnel into the newly completed or renovated facility. The O&M staff is ramping up to assume responsibility for daily operation and maintenance of the facility. Having a well established, clearly documented commissioning plan helps everybody better understand roles, responsibilities, and important functions to perform during this busy period.

G.6.1.2 Building commissioning activities during the project activation phase ensure systems and components are working in accordance with the facility Requirements Document. All system parameters are assessed, including energy, water, environmental, maintainability, and functionality requirements. During the activation phase, O&M and custodial staffs receive final orientation and training to ensure preparedness to operate and maintain the facility. Facility users should be briefed about how their daily activities will affect performance targets and about the sustainability features of the facility.

G.6.2 General Issues to Consider During Activation.

G.6.2.1 Building commissioning activities are most critical during the activation phase. During this phase final component level testing is completed, and integrated equipment and system level FPTs are performed by the contractor, and verified by the CA. As necessary, adjustments and retesting must be performed, normally under very tight time constraints, and coincident with users trying to move into the facility.

G.6.2.2 The O&M staff begins operating equipment under actual conditions. The activation phase provides an excellent opportunity to put equipment through a "dry run," before the facility becomes fully occupied. This allows initial lessons to be learned.

G.6.3 Action Items. The sustainability team should consider the actions in the following paragraphs during the Activation Phase to ensure the project maximizes the sustainability objectives.

G.6.3.1 Conduct Final Training and Orientation - Verify that occupants, O&M staff, and custodial contractors understand building systems and proper procedures and use of sustainable design features such as operable windows and lighting controls.

G.6.3.2 Establish O&M Baselines - Establish a baseline of operating parameters for the operations and maintenance program. Consult metrics and lessons learned from previous projects, as well as, industry norms and manufacturer specifications. Use this baseline to assess facility degradation during the life of the facility, and to trigger appropriate maintenance or repair activities in the future.

G.6.3.3 Building Commissioning in Project Activation - A number of important actions including those listed in the following paragraphs remain to complete the commissioning process.

a. Energize and test equipment - Many component-level FPT's can and should be performed before equipment startup to minimize the disruptions to the startup process. Many of these early FPTs occur during the construction phase. After initial FPTs are satisfied and equipment installation is complete, the remaining component-level FPT's can be completed.

b. Perform Component-level FPT's - Component-level FPT's exercise the simplest assemblies in our systems, such as switches, relays, sensors and actuators. The FPT's are relatively simple and deficiencies tend to be easy to troubleshoot and correct. Examples of component-level FPT's include calibration of outside air temperature sensors, over-current response time of an electrical protective device, the ability of a damper motor to smoothly modulate the damper between full open and full closed. For critical components, such as protective devices, the tests are quite sophisticated, requiring expensive equipment and operator expertise. Component-level FPT's lend themselves to standardization. Judgment must be exercised to select the level of rigor applied to testing a particular component. For example, an outside air temperature sensor needs to be accurate over a wide range of temperatures, so calibrating it at two temperatures may be warranted. However, a room temperature sensor may only see a few degrees of variation, so a single temperature calibration at the control set-point temperature may be adequate.

c. Perform Balancing & Verification - Testing, adjusting and balancing (TAB) is a critical component of the commissioning process. If the contractor performs balancing, then the commissioning process verifies the results. It is recommended that the balancing agency demonstrate the accuracy of a sample of their final readings when they finish their work. If the readings do not correspond to their report, then the report is rejected.

d. Consider ambient and load conditions - Some system and intersystem FPT's are dependent upon ambient or occupancy conditions. These FPT's will be performed later and should be excluded from functional completion schedule requirements.

e. Witness FPTs - The contractor performs preliminary functional tests to make sure all equipment and systems work as required. The contractor then demonstrates to the CA, or some other owner witness, some or all of the FPT's to prove their success. The results of the FPT demonstrations determine whether the commissioning work will be accepted. It is important, therefore, to make sure a knowledgeable witness is present to observe the demonstrations, and to countersign the test data records to authenticate them.

f. Look-Ahead Schedules - The contractor should create look-ahead commissioning schedules before activation FPT testing begins, and update them frequently during the activation phase. Look-ahead schedules contain the following information for each FPT required during the scheduled period: FPT number and title, equipment or systems to be tested, starting date, time and duration, starting location, contractors and suppliers who must attend or be available on site during the tests, and a list of test equipment or instruments with identification of who is responsible for providing them. Two-week commissioning look-ahead schedules may not be necessary for very small projects; simple test schedule notification forms may be adequate for the few tests involved.

g. Perform System FPT's - System FPT procedures are more complex and tend to be created for each individual project, perhaps starting from a similar procedure used previously. System FPT's exercise discrete systems, such as the emergency power system, the heating water system, or an air handling system, through a full range of operating conditions and loads. For example, for an air handling system there may be an FPT for outside air volume control that would measure the volume of outside air as the economizer modulated and as the total system flow varied. Every normal and emergency mode of operation is tested under the full range of loads.

h. Perform Intersystem FPT's - When all systems involved in a particular interface have been successfully tested, the intersystem operation of those systems can be verified. Intersystem FPT's are the most complex, and usually the most interesting tests. A typical test involves disconnecting the building from the electric utility grid and verifying the performance of various systems that are required to respond in an emergency power mode of operation. The fire alarm system should function without interruption of abnormalities. Some portions of the HVAC system may remain active, and may have a specific mode of operation for emergency power. Lighting controls may be required to reconfigure lighting. The security system would be expected to operate normally, without compromising safe egress or unauthorized entry. During the emergency power condition, create a fire alarm condition. Again, verify that all systems respond in the prescribed manner. Finally, restore normal power and check that all systems return to normal operation without human intervention. Other intersystem tests may involve space temperature control under natural or false loads, and indoor air quality under simulated or real occupant loads.

i. Track Deficiency Resolution - In the course of commissioning, conditions will be discovered that are at variance with contract requirements or the Requirements Document. These variances are referred to as deficiencies. When deficiencies have been corrected, written correction reports initiate retests to verify that the corrections were complete and effective. The construction contractor must track these deficiencies from discovery to correction and successful retesting.

j. Set Up Performance Monitoring - Misaligned equipment drifts out of adjustment quickly, creating conditions for premature failure. The benefits of commissioning are enhanced by monitoring the performance of equipment and systems throughout the life of the facility. Part of the commissioning process is to establish performance-monitoring tools. The contractor establishes data trend logs and alarms to alert the operations and maintenance staffs when performance deteriorates, indicating the need for service, or in extreme cases, replacement under the manufacturers warranty. Verification of the proper operation of the alarm points and trend logs is included in commissioning.

k. Incorporate New Equipment into Maintenance Program - New equipment and systems must be included in the owner's maintenance management program. Either the contractor or the CA may be hired to assist the facility staff or maintenance contractor in entering information about the new equipment and systems into the maintenance management program. Otherwise, the facility staff or maintenance contractor needs to complete this task prior to or immediately after substantial completion. Information required for each piece of equipment includes: inventory number, equipment name, location (building, floor, room, zone), manufacturer, model and serial number, date acquired, and size (capacity, voltage, current, weight, horse power, or dimensions).

G.6.3.4 Safety and Security During Activation - During the activation process safety and security systems will undergo their final system FPTs. Safety and security advocates should ensure their systems operate according to the facility project requirements. Appropriate operational and maintenance training for these systems should be performed during the activation phase.

G.7 Operations and Maintenance (O&M)

G.7.1 O&M Overview. This Section identifies issues and actions required to ensure a facility continues to meet the requirements established in the facility Requirements Document, while consuming a minimal amount of O&M

resources.

G.7.2 General issues to consider during facility O&M

G.7.2.1 Centers must produce projects that support their O&M philosophy. That philosophy must be consistent with NASA NPG 8831.2D, Facilities Maintenance Management and the NASA Reliability Centered Maintenance Guideline. These policies encourage the use of modern maintenance practices, combining a prudent mix of reactive, preventive, predictive and proactive maintenance.

G.7.2.2 Centers must budget adequate resources to continue the proactive maintenance program established during the planning, design, construction and activation of the facility. Careful planning went into the creation of an optimal O&M program. Deviations from the program due to budget adjustments must only be made with a full understanding of the life-cycle cost ramifications.

G.7.2.3 Centers must evaluate O&M contract requirements to ensure contractors can support recommended O&M programs. In many cases, O&M contractor involvement during earlier phases of project development is crucial and Centers must budget to allow for contractor participation. Input from the contractor community regarding latest trends and industry practices for O&M are encouraged. Appropriate funding is needed to provide required training for O&M staff.

G.7.2.4 Perform periodic re-commissioning, to verify that facility performance continues to meet the OPR. This regular comparison will identify drop offs in facility performance, and allow appropriate adjustments to maintain performance at or near optimal levels. As part of this ongoing evaluation process, the O&M staff should establish lines of communication with building occupants, so any notable anomalies are promptly identified. Tool 7B in the Construction Industry Institute (CII) Maintainability Implementation Guide (1999) provides a sample user feedback mechanism.

G.7.3 Action Items. The project team should consider the following action items during the O&M phase to ensure the project maximizes the sustainability objectives:

a. Optimize O&M operations by considering the following:

(1) Following established O&M procedures, and adjusting procedures appropriately based upon actual experience. Collect data regarding equipment failures and causes, and performing appropriate failure analyses to determine required adjustments to existing O&M programs. Use condition feedback data, and lessons learned as well.

(2) Measuring effectiveness of O&M operations. Tool 16 in the CII Maintainability Implementation Guide (1999) and the NASA NPG 8831.2D provide listings of metrics to consider.

(3) Providing appropriate incentives to continually encourage improvements in O&M programs.

(4) Maintaining a lessons learned file for maintainability suggestions and best practices.

(5) Conducting periodic maintainability assessments, focusing on opportunities to improve the O&M program.

b. Protect and conserve water by using environmentally friendly landscaping practices, planting native species to minimize irrigation, fertilization and pest control requirements, and using gray water systems for irrigation,

c. Use environmentally preferable products for O&M and user requirements, including recycled content materials and use of high efficiency equipment,

d. Use environmentally preferable cleaning products,

e. Establish reuse and recycling programs to eliminate offsite waste disposal,

f. Enhance IEQ by using properly sealed vacuum cleaners, regularly cleaning heating , ventilation, and air-conditioning (HVAC)ducts and filters, and if installed, using air quality monitors to assess IEQ,

g. Minimize energy consumption by utilizing the following:

(1) Measuring overall consumption against target levels,

(2) Refer to original design criteria, and if necessary consult with the original design team when making adjustments to HVAC systems,

(3) Maintain training for O&M personnel to ensure systems are properly operated and maintained,

(4) Providing facility users basic training on the function of critical systems, and a mechanism for providing feedback regarding operational problems, and

(5) Effectively using automated monitors.

h. After activation, any follow on commissioning activities are the owners responsibility. Some possible commissioning activities include the following:

(1) Ensure the CA follows up on any deferred FPTs that could not be completed during the activation phase. Deferred FPTs may be called for if seasonal conditions prevent full loading of critical systems.

(2) Perform FPTs, and apply appropriate PT&I tests prior to expiration of warranty. These tests will ensure there are no latent defects evident prior to the warranty expiration date. The commissioning plan should have identified end-of-warranty testing requirements.

(3) Perform periodic condition monitoring tasks using predictive technologies.

(4) Retain and refer to commissioning documentation as a baseline to compare ongoing O&M performance.

i. Safety and Security Issues - After occupancy, safety and security advocates should remain aware of system performance compared to original project requirements. As facility or operational requirements change, appropriate changes to safety or security systems may be warranted.

G.8 Decommissioning

G.8.1 Decommissioning Overview. This Section describes a decommissioning phase in the acquisition process to bring attention to the opportunities to continue sustainability concepts through the full facility life cycle. Properly planned, designed and constructed facilities should consider the final disposition of the facility to minimize impacts to the environment. In addition, well-planned facilities can save resources as facilities transition from one use to another.

G.8.2 General issues and action items to consider during facility Decommissioning

G.8.2.1 Evaluate whether demolition, conversion, transfer, or lease is an appropriate decommissioning method. When a building or space reaches the end of its useful life, converting the structure for an alternate use is normally preferable to demolition. In cases where the facility is excess to NASA requirements, options including transfer to other agencies or lease/reuse to other entities should be considered.

G.8.2.2 Consider deconstruction rather than demolition. Deconstruction provides many opportunities for waste reduction, reuse, and recycling of building materials and components. Deconstruction also reduces material costs for the converted facility. Actions items related to deconstruction include the following:

a. Consider deconstruction when adaptive reuse is not an option;

b. If the facility was designed with deconstruction in mind (not likely for older facilities), evaluate what components can be easily salvaged for reuse or made available for recycling (i.e., high value items like antique brick, hardwood flooring, large structural timbers, modern mechanical equipment, and specialty masonry, woodwork or metalwork). Maintain a network of salvage and recycling firms in your area;

c. Maintain an on Center location for storing reusable items;

d. Coordinate reuse of salvaged items by specifying their use in projects under design and development;

e. Avoid salvage and reuse of low-efficiency equipment; and

f. If demolition is used, ensure the demolition contractor follows reasonable processes to minimize land filled materials. Actions to promote this include the following:

(1) Allow the demolition contractor rights to all materials that are not salvaged. It is probable that such contractors will have better insight into what materials can be reused or recycled, and their proposed price may reflect the proceeds from these activities,

(2) Ensure hazardous materials are properly identified, and require disposal in accordance with applicable laws and regulations, and

(3) Coordination with the Headquarters Environmental Management Division.

ATTACHMENT G1. References

This attachment includes significant references and resources for implementing sustainability concepts on NASA projects. Additional references are available through the Whole Building Design Guide.

AG1.1 Federal Mandates:

Executive Order 13123, "Greening the Government Through Efficient Energy Management" National Construction Goals.

AG1.2 Publications:

AG1.2.1 Green Buildings - Guidelines for Creating High-Performance Green Buildings by the Pennsylvania Department of Environmental Protection. 1999.

AG1.2.2 Greening Federal Facilities Guide by U.S. Department of Energy. 2001.

AG1.2.3 High Performance Building Guidelines) by New York City Department of Design and Construction. April 1999.

AG1.2.4 Maintainability Implementation Guide (1999). Construction Industry Institute (CII), University of Texas at Austin, Austin, TX.

AG1.2.5 Sustainable Federal Facilities - A Guide to Integrating Value Engineering, Life-Cycle costing, and Sustainable Development by Federal Facilities Council. Washington, DC: National Academy Press, 2001.

AG1.3 Organizations:

AG1.3.1 Sustainability

AG1.3.1.1 Sustainable Buildings Industry Council (SBIC)

AG1.3.1.2 U.S. Green Building Council (USGBC)

AG1.3.2 Enhance Indoor Environmental Quality. The following are relevant codes and standards:

a. ASHRAE Standard 55-1992 - Thermal Environmental Conditions for Human Occupancy, 1992,

b. ASHRAE Standard 62-1999 - Ventilation for Acceptable Indoor Air Quality, 1999. Sets the minimum acceptable ventilation requirements.

c. American Society of Heating, Refrigerating, Air-Conditioning Engineers (ASHRAE)

d. American Society for Testing and Materials (ASTM)

e. Illuminating Engineering Society of North America (IESNA)

f. Indoor Air Quality Web site, EPA

g. Multizone Modeling web site, NIST Contains software tools for performing multizone analysis (e.g. CONTAMW), information on the applications of multizone modeling, multizone modeling case studies, and references to multizone modeling publications.

h. Occupational Safety and Health Administration (OSHA)

i. Sheet Metal and Air Conditioning Contractors Association publishes Indoor Air Quality Guidelines for Occupied Buildings Under Construction. The standard can be ordered at SMACNA, 4201 Lafayette Center Drive, Chantilly, VA 20011-209.

AG1.4 Relevant Codes & Standards

AG1.4.1 Minimize Energy Consumption:

AG1.4.1.1 Executive Order 13123, "Greening the Federal Government Through Efficient Energy Management"

AG1.4.1.2 WBDG -

a. Minimize Energy Consumption and Energy Codes & Standards

b. Energy Analysis Tools

AG1.4.1.3 Energy Star©, EPA

AG1.4.1.4 Federal Energy Management Program (FEMP), DOE

AG1.4.1.5 High Performance Commercial Buildings: A Technology Roadmap by U.S. Department of Energy.

AG1.4.2 Optimize O&M Practices

AG1.4.2.1 (NASA NPG 8831.2D, Facilities Maintenance Management

AG1.4.2.2 NASA RCM Guideline

AG1.4.2.3 NASA Reliability Centered Building and Equipment Acceptance Guide

AG1.4.3 Optimize Site Potential

AG1.4.3.1 Executive Order 13148, Greening the Government Through Leadership in Environmental Management

AG1.4.3.2 Executive Order 13006, Locating Federal Facilities on Historic Properties in Our Nations Central Cities

AG1.4.3.3 Executive Order 12072, Federal Space Management

AG1.4.4 Protect & Conserve Water. Executive Order 13123, Greening the Federal Government Through Efficient Energy Management

AG1.4.5 Use Green Products

AG1.4.5.1 Executive Order 13101, Greening the Government Through Waste Prevention, Recycling, and Federal Acquisition

AG1.4.5.2 ASTM 2129 - Standard Practice for Data Collection for Sustainability Assessment of Building Products

AG1.4.5.3 ISO 14040 Series - Life-Cycle Assessment Standards

AG1.4.5.4 WBDG -

a. Building Integrated PV (BIPV)

b. Electric Lighting Controls

c. Energy Efficient Lighting

d. Fuel Cell Technology

e. Green Products

f. High Performance HVAC

g. Life-Cycle costing

h. Solar Water Heating

i. Sun Control & Shading Devices

j. Windows & Glazing

k. Choose Green Report

AG1.4.5.5 Energy Star©, EPA

AG1.4.5.6 Environmental Building News

AG1.4.5.7 Environmental Design & Construction Magazine

AG1.4.5.8 Green Building Network materials sourcebook, City of Austin Green Builder Program

AG1.4.5.9 Green Building Resource Guide by John Hermannsson. Taunton Press, 1997

AG1.4.5.10 GreenSpec™ - The Environmental Building News Product Directory

AG1.4.5.11 GSA Federal Supply Service Environmental Products and Services Guide

AG1.4.5.12 Guide to Resource Efficient Building Elements by Tracy Mumma. National Center for Appropriate Technology's Center for Resourceful Building Technology, Missoula, MT. Online version

AG1.4.5.13 oikos© Green Building Source - Green Product Information

AG1.4.5.14 PATHNET.org - Excellent repository of building materials, case studies, and innovative techniques

AG1.4.6 Evaluate Environmental Preferability Using LCA:

AG1.4.6.1 WBDG - Life-Cycle costing

AG1.4.6.2 Athena

AG1.4.6.3 BEES

AG1.4.6.4 The Environmental Resource Guide by American Institute of Architects (AIA), Joseph A. Demkin (Editor). New York: John Wiley & Sons, Inc., 1996

AG1.4.7 Maximize the Recycled Content of All New Materials

AG1.4.7.1 WBDG - Green Products

AG1.4.7.2 Comprehensive Procurement Guidelines (CPG), EPA

AG1.4.7.3 Environmentally Preferable Purchasing Program (EPP), EPA

ATTACHMENT G2. Example Solicitation for Commissioning Authority (CA) Selection

The following is an example solicitation for obtaining firms interested in being considered for serving as the NASA Commissioning Authority for projects at the specified location:

NASA will receive submittals of qualifications for firms to serve as the Commissioning Authority for building commissioning services.

Definition: Building commissioning is a quality process emphasizing procedures to ensure that systems are designed, installed, functionally tested, and capable of being operated and maintained to perform in conformity with the owners project requirements. The process begins during project planning and extends through design, construction, activation, and operations and maintenance. Building commissioning concepts can be applied throughout the life of the facility. The following are fundamental principles of building commissioning:

a. Identifying and documenting the functional requirements (user defined), facility requirements (as developed by the project team), and the basis and intent of the design;

b. Establishing processes to verify that project requirements are achieved; using a commissioning plan; using a commissioning authority; and including commissioning requirements in construction contracts; and

c. Using functional performance testing and predictive technologies to ensure proper facility operation and to identify and eliminate latent defects prior to accepting new facilities or equipment (incorporating all the elements of NASA's RCBEA program).

Commissioning, during the construction phase is intended to achieve the following specific objectives according to the Contract Documents:

Verify that applicable equipment and systems are installed according to the manufacturer's recommendations and to industry accepted standards and they receive adequate operational checkout by installing contractors.

a. Verify and document proper performance of equipment and systems,

b. Verify that O&M documentation left onsite is complete,

c. Verify that the owner's operating personnel are adequately trained, and

d. Verify compliance with NASA Design and Construction Standards.

NASA will contract directly with selected firm(s). Commissioning services may include the following:

a. Commissioning plan development;

b. Commissioning budget development;

c. Review of Design Intent, Basis of Design, design drawings and specifications, control interface diagrams and one-line diagrams at several design phase milestones;

d. Preparation of detailed commissioning specifications;

e. Reviewing contractor submittals of updated commissioning plan and schedule, shop drawings and product submittals;

f. Leading and documenting commissioning meetings;

g. Preparing functional performance test procedures;

h. Assembling O&M materials into a systems manual; and

i. Witness contractor execution of startup, flushing and cleaning, and functional performance tests.

Projects to be commissioned include extensive complex systems with building construction costs exceeding $10 million. Potential projects include the __________ Addition (__,000 gsf), the _______________ Building (__,000 gsf), and the _______________ Expansion/Renovation (__,000 gsf). These facilities variously include offices, classrooms, auditoria, teaching and research laboratories, state-of-the-art VAV air conditioning systems, laboratory utilities, chillers, cooling towers ___________ and __________will start construction during 2000. ______________ will bid in summer 2001. Each construction period will be about ___ months.

Plans are available for review in the ______ Office at (NASA Facility). Review prior to qualifications submittal is not required.

Preferred qualifications include a minimum of three years of hands-on commissioning experience with elements of general construction such as roofs, wall assemblies, automatic doors, controlled-environment chambers, VAV supply and exhaust ventilation systems with off-set tracking control for laboratories, fume exhaust systems, chillers, cooling towers, laboratory utility services, DDC environmental control systems, fire alarm systems, electrical primary and secondary distribution, substations, switchgear, breaker coordination, motor controls, variable frequency drives, energy conservation measures.

Interested and qualified firms are invited to submit a statement of qualifications consisting of the following:

a. History of the company;

b. Commissioning expertise and capability;

c. Local experience over the last 3 years on projects of similar size and scope;

d. Reference contacts with telephone numbers;

e. Resumes of key management personnel and their positions;

f. Qualifications of personnel to be assigned to NASA projects, their certifications and commissioning responsibilities;

g. Personnel rate schedule;

h. Location of the firm and proximity to the work site; and

i. Professional liability insurance.

Submittals shall include three (3) copies each of a letter of interest, the above listed information, and completed SF 254 Form.

NASA is an affirmative action/equal opportunity employer and encourages minority and women owned firms to participate.

NASA may interview some firms responding to this solicitation. Firms invited for interview will be required to present comprehensive evidence of commissioning documents developed for a similar project commissioned by the firm. Final selection, in each case, will be based upon the qualifications listed above, in comparison to the needs of the project, and the quality of the documents provided during the interview. Review documents will be returned to the applicant at the end of the interview. Firms selected for final consideration will be notified on or about _____________, 2001.

Send submittals to: (NASA Address)

Submittals must be received no later than 5 p.m. on ___________, 2004.

ATTACHMENT G3. Example Functional Performance Testing Documents and RCBEA testing Specifications

AG3.1 Example Functional Performance Test Documents. In this section examples of commissioning documentation related to Functional Performance Tests (FPT) are provided to clarify the level of detail required in the execution and documentation of commissioning procedures. The following is a list of the three documents involved, all relate to the same functional performance test.

a. FPT specification: the specifications are included in the bid documents. The example in paragraph AG3.1.1, illustrates the level of detail necessary to convey to bidders the scope of their work for a specific test. On a typical project, there may be between 20 and 100 similar FPT specifications for mechanical components and systems.

b. FPT Procedures: the procedures are the detailed instructions of how to execute a specified FPT. An example FPT procedure is provided in paragraph AG3.1.2.

c. FPT Data Forms: the data forms provide a written record of the performance observed during the execution of the FPT procedure. An example FPT data form is provided in paragraph AG3.1.3.

AG3.1.1 Example: FPT Specification

Functional Performance Test Specification

(17550.3.3.F)

FPT: Air Handling Unit - Supply Air Control

1. System/Equipment to be Tested: AHU-1 and associated controls.

2. Functions to be tested: Damper and control valve operation to maintain

a. Air temperature at setpoint and

b. Minimum outside air.

3. Conditions of the Test: System shall be in occupied mode.

a. Test operation with outside air temperature below 45°F, at approximately 60°F, and above 82°F.

b. Test system at 100-percent, 65-percent and 25-percent, airflow.

Repeat conditions i) and ii) with carbon dioxide concentrations above 800 PPM in the return air stream.

4. Acceptable Results:

a. Discharge air temperature shall be within +/-1°F of setpoint for all outside air conditions.

b. Outside air volume shall be within -0 percent and +5 percent of scheduled minimum under minimum outside air conditions. Under all other conditions, outside air volume shall vary according to the economizer sequence of control.

c. Outside air volume shall modulate to maintain carbon dioxide levels below 800 PPM.

AG3.1.2 Example: FPT Procedure

Functional Performance Test Procedure

FPT #17550-6
AHU-1 Supply Air Control

Objective:

To demonstrate proper operation of the AHU-1 supply air control, as required by specification 17550.3.3.F.

Prerequisites:

Successful completion of component FPT's, including calibration for all control points associated with operation of this air handler. Successful completion of preceding FPT procedures specified in this Section. Successful completion of heating water and chilled water systems FPT's as specified elsewhere. Successful completion of balancing.

Participants:

Commissioning Coordinator, one EMCS control contractor technician, one HVAC contractor technician, Owner's Witness.

Tools & Equipment:

DDC-08 (Portable control system interface): by EMCS subcontractor.

Procedure:

Set up a trend log with sampling at 30 second intervals for the following points:

1. Outside air temperature input

2. Supply air temperature input

3. Return air temperature input

4. Mixed air temperature input

5. Minimum outside air volume input

6. Main outside air volume input

7. Carbon dioxide sensor input

8. Minimum outside air damper output

9. Main outside air damper output

10. Return air damper output

11. Heating valve output

12. Cooling valve output

A. Outside air temperature below 45°F, 100-percent system volume:

1. Observe and record the outside air temperature.

2. If outside air temperature is above 45°F, override the sensor input with a 42°F value. Record value.

3. If outside air temperature is above or near the supply air temperature setpoint, reset the supply air temperature setpoint upward to create a demand for heating. Record value.

4. With system in occupied mode, command all terminal units to 100-percent open. Observe and record position of minimum outside, main outside, exhaust, and return air dampers. Record outside air volume.

5. Observe and record positions of heating and cooling valves.

6. Observe and record supply air temperature.

B. Outside air temperature below 45°F, 65-percent system volume:

1. With system in occupied mode, command sufficient terminal units to minimum position to reduce system volume to 65-percent of maximum. Observe and record position of minimum outside, main outside, exhaust, and return air dampers. Record outside air volume.

2. Observe and record positions of heating and cooling valves.

3. Observe and record supply air temperature.

C. Outside air temperature below 45°F, 25-percent system volume:

1. With system in occupied mode, command sufficient terminal units to minimum position to reduce system volume to 25-percent of maximum. Observe and record position of minimum outside, main outside, exhaust, and return air dampers. Record outside air volume.

2. Observe and record positions of heating and cooling valves.

3. Observe and record supply air temperature.

D. Outside air temperature between 45°F and 82°F, 100-percent volume:

1. Observe and record the outside air temperature.

2. If outside air temperature is below 45°F, or above 82°F, override the sensor input to a value 5°F below return air temperature. Record value.

3. If outside air temperature is below or near the supply air temperature setpoint, reset the supply air temperature setpoint downward to create a limited demand for cooling. Record value.

4. With system in occupied mode, command all terminal units to 100-percent open. Observe and record position of minimum outside, main outside, exhaust, and return air dampers. Record outside air volume.

5. Observe and record positions of heating and cooling valves.

6. Observe and record supply air temperature.

E. Outside air temperature between 45°F and 82°F, 65-percent of maximum volume:

1. With system in occupied mode, command sufficient terminal units to minimum position to reduce system volume to 65-percent of maximum. Observe and record position of minimum outside, main outside, exhaust, and return air dampers. Record outside air volume.

2. Observe and record positions of heating and cooling valves.

3. Observe and record supply air temperature.

F. Outside air temperature between 45°F and 82°F, 25-percent of maximum volume:

1. With system in occupied mode, command sufficient terminal units to minimum position to reduce system volume to 25-percent of maximum. Observe and record position of minimum outside, main outside, exhaust, and return air dampers. Record outside air volume.

2. Observe and record positions of heating and cooling valves.

3. Observe and record supply air temperature.

G. Outside air temperature above 82°F, 100-percent volume:

1. Observe and record the outside air temperature.

2. If outside air temperature is below 82°F, override the sensor input with an 85°F value. Record value.

3. If outside air temperature is below or near the supply air temperature setpoint, reset the supply air temperature setpoint downward to create a limited demand for cooling. Record value.

4. With system in occupied mode, command all terminal units to 100-percent open. Observe and record position of minimum outside, main outside, exhaust, and return air dampers. Record outside air volume.

5. Observe and record positions of heating and cooling valves.

6. Observe and record supply air temperature.

H. Outside air temperature above 82°F, 65-percent of maximum volume:

1. With system in occupied mode, command sufficient terminal units to minimum position to reduce system volume to 65-percent of maximum. Observe and record position of minimum outside, main outside, exhaust, and return air dampers. Record outside air volume.

2. Observe and record positions of heating and cooling valves.

3. Observe and record supply air temperature.

I. Outside air temperature above 82°F, 25-percent of maximum volume:

1. With system in occupied mode, command sufficient terminal units to minimum position to reduce system volume to 25-percent of maximum. Observe and record position of minimum outside, main outside, exhaust, and return air dampers. Record outside air volume.

2. Observe and record positions of heating and cooling valves.

3. Observe and record supply air temperature.

J. Restore outside air temperature sensor input to normal operation.

K. Restore air terminal units to normal operation.

L. Restore supply air temperature setpoint to design.

M. Record date and time of completion of procedure.

N. Retrieve trend log data.

O. Revise trend log sampling rate to 15 minutes.

P. Retrieve trend log data after 7 days.

AG3.1.3 Example: FPT Data Form

FPT #17550-6
AHU-1 Supply Air Control

First test or retest?		____________
Trend log file name		____________
Date/time initiated		____________
Sampling rate (sec., min., hr.)		____________
A.	Outside air temperature below 45°F, 100-percent volume:	
	1. Outside air temperature	
	2. Outside air temperature input override value	____________
	3. Supply air temperature setpoint reset value	____________
	4. Damper positions	
	a. Minimum outside air (100-percent open)	____________

b. Main outside air (0 percent open) ______________________
c. Exhaust air (0 percent open) ______________________
d. Return air (100-percent open) ______________________
e. Outside air flow volume (2100 - 2205 CFM) ______________________
5. Valve positions
a. Heating valve (modulating open) ______________________
b. Cooling valve (0 percent open) ______________________
6. Supply air temperature (setpoint +/- 1°F) ______________________

B. Outside air temperature below 45°F, 65-percent volume:
1. Damper positions ______________________
a. Minimum outside air (100-percent open) ______________________
b. Main outside air (0 percent open) ______________________
c. Exhaust air (0 percent open) ______________________
d. Return air (100-percent open) ______________________
e. Outside air flow volume (2100 - 2205 CFM) ______________________
2. Valve positions
a. Heating valve (modulating open) ______________________
b. Cooling valve (0 percent open) ______________________
3. Supply air temperature (setpoint +/- 1°F) ______________________

C. Outside air temperature below 45°F, 25-percent volume:
1. Damper positions

AG3.2 RCBEA testing Specifications. These specification are included in the NASA reliability Centered Building and Equipment Acceptance Guide available on the NASA Headquarters Code JX web site.

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